REPORT RESUMES

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MATHEMATICAL EXPECTATIONS OF TECHNICIANS IN MICHIGAN INDUSTRIES, A SPECIAL VOCATIONAL EDUCATION RESEARCH PROJECT.

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OBJECTIVES OF THIS STUDY WERE TO DETERMINE THE FUNDAMENTALS OF MATHEMATICS AND COMMON MATHEMATICS SKILLS NEEDED BY TECHNICIANS AND TO DETERMINE IF THESE FUNDAMENTALS AND SKILLS SHOULD BE TAUGHT BEFORE EMPLOYMENT OR AS RELATED ACTIVITIES AFTER EMPLOYMENT. A PILOT SURVEY WAS MADE IN DETROIT TO VALIDATE THE RESEARCH INSTRUMENTS. THE POPULATION WAS 71 COMPANIES, SELECTED ON THE BASIS OF "BEST PRACTICE" AND "MOST PROMISE" WHICH EMPLOYED 23,062 TECHNICIANS. REPRESENTATIVES OF EACH COMPANY WERE INTERVIEWED TO ASCERTAIN THE TYPES OF TECHNICIANS EMPLOYED AND THEIR MATHEMATICS NEEDS. THE RESPONDENTS INDICATED ON A CHECKLIST THE MATHEMATICS FUNDAMENTALS THEY CONSIDERED ESSENTIAL, DESIRABLE, OR NOT NEEDED. IT WAS ESTABLISHED THAT SKILLS IN ARITHMETIC, ALGEBRA, GEOMETRY, AND TRIGONOMETRY (THROUGH RIGHT ANGLES) WERE NEEDED BY ALL CLASSIFICATIONS OF TECHNICIANS. OTHER FINDINGS WERE--(1) PREPARATION PRIOR TO EMPLOYMENT WAS DESIRED BY 27 PERCENT OF THE SUPERVISORS, (2) 2.8 PERCENT OF THE COMPANIES OFFERED TRAINING COURSES, (3) 87 PERCENT OF THE COMPANIES HAD TUITION SUBSIDY PLANS, AND (4) 65 PERCENT PREDICTED THAT, BY 1977, STATISTICS, COMPUTER LANGUAGE, AND CALCULUS WOULD BE REQUIRED OF MANY TECHNICIANS. TABULAR DATA SHOW THE MATHEMATICS FUNDAMENTALS AND SKILLS NEEDED FOR ALL THE TECHNICIAN CLASSIFICATIONS STUDIED. (EM)

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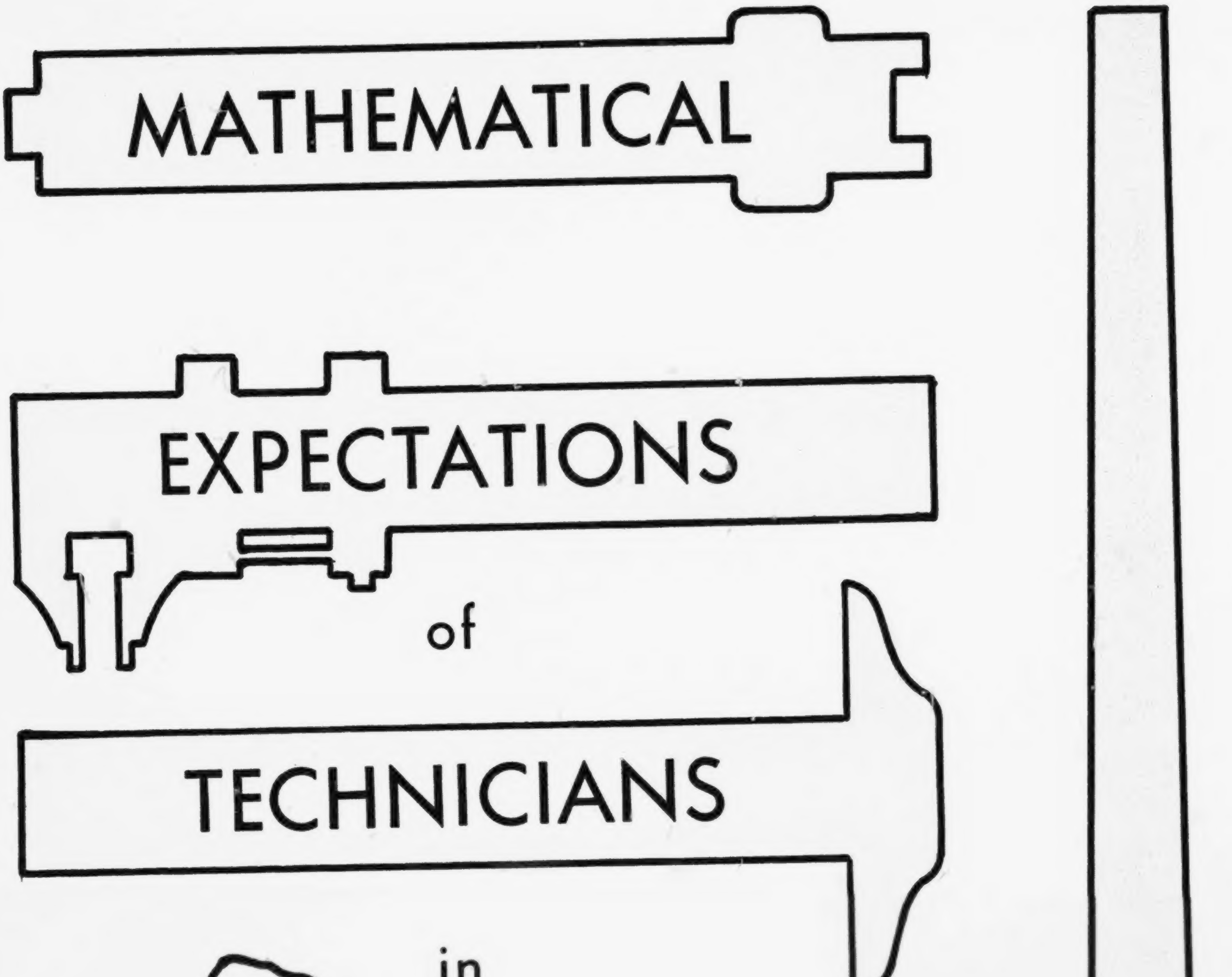

MATHEMATICAL EXPECTATIONS of TECHNICIANS in MICHIGAN INDUSTRIES

VT000901

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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Mathematical Expectations of Technicians in Michigan Industries

— a special vocational education research project —

conducted at
Wayne State University
with assistance from
Henry Ford Community College
from funds provided for research and development by
Michigan Department of Public Instruction
Division of Vocational Education

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July, 1966

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The director and the researcher take this opportunity to note the important contribution made by Task Force One. These business, educational, industrial, governmental, and labor leaders, whose names appear in Appendix C, with their experience and familiarity of Michigan industries, provided recommendations that were most important in selecting companies to be interviewed.

The high percent of response from industry is evidence of the fine cooperation received. The director and the researcher were especially impressed by the many executives who so graciously gave of their time and who extended courtesies, so that the study could be accurate and complete.

Professional services were provided by the faculties of both Wayne State University and Henry Ford Community College. Especially helpful in the areas of their specialties were Dr. Wilhelm Reitz in educational research, Dr. Sigurd Rislov in higher education, Professor Gordon E. Rivers in engineering, and Dr. Eugene P. Smith in mathematics education. Individuals from the service areas of both institutions also assisted. The services of Helge E. Hansen (audio-visual director), Carol Waarala (secretary), and Henry Czerwick Jr. (illustrator) are gratefully acknowledged.

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CHAPTER I

A Special Michigan Vocational Education Research Project

Introduction

Title of Project

Mathematical Expectations of Technicians in Michigan Industries

Problem

A survey conducted by the President's Committee on Scientists and Engineers indicated that the scope of mathematics was the most critical determinant for both the level and the quality of technological curriculums. Probably, the most common criticism among graduates and employers was directed at the mathematical content of such curriculums.[1]

To maintain the ratio of technicians to engineers (0.7 to 1), the 775,000 technicians employed in 1960 must increase (521,700 or 67.3 percent) to 1,396,700 by 1970. The increase must be 695,000 yearly by 1970, if losses due to deaths, retirement, and job changes are considered. Also, if the technician ratio is to be increased (2 to 1), the number of technical graduates yearly must increase to about 803,300.[2] The 701 two-year colleges offering technical curriculums in 1963, represented a 300 percent increase from 1950,[3] and it seems evident that in the State of Michigan the percent of increase will need to be even greater in the next decade.

It seemed essential then to determine what fundamentals of mathematics are necessary for technicians so that existing and future curriculums will better prepare these students for their place in a technological society.

Specific Objectives of the Study

1. To determine the fundamentals of mathematics needed by various kinds of technicians to more effectively perform their jobs in Michigan's industries.

2. To determine whether certain common skills in mathematics were needed by all technicians.

3. To determine if essential mathematical skills should be taught to the student prior to employment, or if instruction should be provided as a related activity while the technician is employed.

4. To prepare manuscript for a bulletin summarizing the findings, conclusions, and recommendations of the study.

5. To use the research information for a project of greater depth that will parallel this study. While the second study will serve as partial fulfillment of the requirements for the Ed.D. degree and will contain many details, such as a review of the literature, not contained in the bulletin (item 4), this study and the doctoral dissertation of Norman G. Laws at Wayne State University were planned to complement each other.

Design and Function

Major Steps in Conducting the Research

1. A pilot survey was made of selected and accessible firms in the Metropolitan Detroit area to validate research instruments. Procedures and instruments for data gathering, in the pilot survey, were analyzed by the researcher, the director, and the advisers for needed revisions before conducting the total project.

2. A task force of selected leaders from government, labor, and industry assisted in determining the firms to be contacted. The members of Task Force One appear in Appendix C. The firms that were surveyed were selected on the basis of their leadership in "best practice" and "most promise" in respect to the use of technicians, as judged by Task Force One. These companies were chosen from those employing more than five hundred persons and located in the Standard Metropolitan Statistical Areas of the State of Michigan, as defined by the Bureau of the Budget.[4]

3. Each firm nominated was contacted. A letter requesting cooperation (as shown in Appendix B) was sent to the president. This letter provided the opportunity for the president of the firm to designate the name and title of the person, or persons, with whom the researcher could work. It was anticipated that a response at this level would assure cooperation. Another purpose was to provide an opportunity for top management of industry to suggest persons, in their organization, who could help formulate educational requirements for technicians in Michigan industries.

4. The researcher then interviewed the designated personnel at the firms selected (as shown in Appendix E) in the metropolitan areas of Ann Arbor, Bay City, Flint, Grand Rapids, Jackson, Kalamazoo, Lansing, Muskegon, and Saginaw during the summer and fall

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[1] The President's Committee on Scientists and Engineers, *Report on Technical Institute Curricula* (Washington: Office of Civil and Defense Mobilization, 1959), pp. 44-46.

[2] Prakken (ed.), *Technician Education Yearbook* (Ann Arbor, Michigan: Prakken Publications, Inc., 1963), pp. 71-75.

[3] *Ibid*, pp. 9-47.

[4] *Standard Metropolitan Statistical Areas* (Washington, D.C.: Office of Statistical Standards, 1964), p. 52.

of 1965. Interviews continued with the survey in the Detroit metropolitan area.

The use of a tape recorder expedited each interview and provided the researcher with an accurate and complete record so that the information obtained could be analyzed. Data were summarized in the form presented as Table 3.

5. Interviewees were furnished with enough mathematical checkoff lists (as shown in Appendix B), and return envelopes, to route a set to each major type of technical worker that had been identified.

6. The analysis of data was made with the help of personnel and equipment at the Wayne State University Research Center. Through the use of percentages and ranking categories, conclusions were drawn, observations made, and recommendations formulated.

7. The manuscript for a bulletin was prepared and released by Wayne State University, in cooperation with the Michigan Department of Public Instruction, Division of Vocational Education, and sent to selected persons and institutions interested in the preparation of technicians in the State of Michigan. A limited number of copies were sent to additional individuals throughout the United States who have been identified as currently interested in educational programs to prepare technicians for industry.

Personnel and Facilities for the Research

Dr. G. Harold Silvius, Professor and Chairman, Department of Industrial Education, College of Education, Wayne State University, directed this research. The researcher was Norman G. Laws, instructor at Henry Ford Community College in Dearborn. As the need arose, other members of the Wayne State University faculty were consulted in areas of their respective specialties.

The Henry Ford Community College provided the necessary office facilities for the researcher, and Wayne State University provided office and consultation space for the director. Both institutions made available the needed office equipment, furniture, and machines.

Personnel at the service facilities of the Audio-Visual Departments, Computer Center, and Printing Department at both Wayne State University and Henry Ford Community College, were called upon for assistance.

Methodology

Interview Procedures

The basic purpose of the interview was to ascertain company policy in the use of technicians. A copy of this interview instrument appears in Appendix B. Persons in a position to actually hire personnel, or to set up guide lines for such hiring, were interviewed as to their mathematical expectations for technicians. Questions were devised to discover what management thought were the mathematical requirements of technicians, whom they had employed, or would employ in the future. This initial interview was planned to set the stage for the second phase of the inquiry — the mathematical checkoff lists (as shown in Appendix B).

Basic to each interview, was the establishment of a working definition for a technician (found in Appendix B). While this definition (which is a composite from definitions supplied by the Association of Manufacturers, the American Society for Engineering Education, and others) had been sent to the individual (or individuals) previous to the interview, the researcher, during the preliminary remarks at each interview, explained (for the purpose of this study) that he was concerned with the high school graduate who needed additional training, either formal or informal, so that he could assist the engineer, scientist, or skilled tradesman in doing the more routine engineering functions in industry — and that this definition did not encompass a person who was a certified scientist or engineer, or who had obtained a bachelor's degree, as a requirement for the particular pay-roll assignment. It was further stressed that this study excluded those positions that would be filled by skilled tradesmen, who had completed a recognized apprenticeship program. It was suggested that the technician usually performs a broader function than the skilled tradesman. Interviewees were appraised, also, of twenty-two sample technician titles (as noted in Appendix B) that seem to be popular.

With this background, the question was asked, "What types of technicians do you employ in your company?". The basic purpose of this question was to ascertain the number of mathematical checkoff lists that should be left with the company. It was then requested that the immediate supervisor or senior technician, for each type of technician identified, fill out the mathematical checkoff list (shown in Appendix B) to indicate the elements of mathematics that the workers under his supervision and direction, use in their day-to-day operation.

As an additional clue to the sophistication of the technician being employed in a particular company, the interviewee was asked about the work experience and education of technical personnel. This was to determine if personnel doing such work were usually reassigned within the company, and, if so — if it was thought that this was an indication that the needed post-high-school preparation was largely a matter of on-the-job experience. When this was not the case, it was then assumed that the technician on the job could have been the product of a post-high-school institution. The question also provided a clue as to what type of institutions were supplying needed technical personnel. Each interviewee was asked to further indicate the basic amount of mathematics that he thought all technicians in his company needed. It was recognized that the response would be much more general than that which would later be received from the mathematical checkoff list, but these data were considered significant in determining requirements of employers. Thus, the purpose of the interviews was to determine, from the viewpoint of management, the amount and types of mathematics that the technician needed, to perform the job.

The inquiry further pursued the question of whether or not the technician should be taught all basic mathematical skills while in school, or if he should continue to learn mathematics while on the job. This was done by inquiring about the mathematical deficiencies that had been noted among technical workers. Then there was an inquiry into company encouragement for additional schooling through incentive programs such as tuition refund, in-service training programs, and motivation efforts to encourage the worker to extend mathematical competency. Interviewees were asked, also, about the mathematical needs of technicians in the decade ahead.

The researcher then provided an opportunity for the interviewees to make specific recommendations relative to curriculums in technical mathematics. Persons were asked if there were basic topics in mathematics that (1) should be given more emphasis, (2) should be included or excluded, and (3) if there were new types of mathematics, especially those involving computers and new industrial approaches, that should be added. Finally, they were asked if they had additional recommendations relative to the way mathematics for technical students should be taught.

Mathematical Checkoff List Procedures

The mathematical checkoff lists provided an opportunity for technical workers (or their immediate supervisors) to describe in greater detail the mathematical needs of the technician. It was felt that the worker could best judge the mathematics involved in the daily operation of his job.

There were six subject sections on each form: Arithmetic, Algebra, Geometry, Trigonometry, Calculus, and Additional Mathematics. Within each category, the various fundamental skills were listed. These had been worked out carefully with members of the Henry Ford Community College Mathematics Department and reviewed by Dr. Eugene P. Smith of the Department of Mathematics Education at Wayne State University. Within each category, space was provided for additional comments, but few were made.

Most of the forms were returned promptly but a few required follow-up. After a second reminder, a telephone call was made and finally 91.7 percent of the forms were returned (a few more were received too late for classification).

Selection of Companies That Were Involved

Selection of Areas

Early in the planning for this study, it was determined that a random sample approach, in surveying industry to determine the mathematical needs of technicians, might not be enlightening. What the investigators were concerned about were those industries, and those companies, which were showing leadership in "best practice" and "most promise" as these factors relate to the use of technicians. It was thought that this could best be accomplished by surveying selected larger companies in the more highly industrialized areas of the State.

In 1949, the Bureau of the Budget of the Executive Office of the President of the United States defined the Standard Metropolitan Areas as the Standard Metropolitan Statistical Areas of the United States, to replace four different sets of definitions that had been in use for various governmental statistical studies. Thus, this new designation replaces the previous designations of Metropolitan Districts, Metropolitan Counties, Industrial Areas, and Labor Market Areas. The primary objective was to standardize the definitions of metropolitan areas, and to make it possible for all federal statistical agencies to use the same boundaries in publishing statistical data.[5] The general concept of a metropolitan area is one that is integrated economically and socially with a recognized large population nucleus. Thus each Standard Metropolitan Statistical Area must contain at least one city of 50,000 inhabitants. A Standard Metropolitan Statistical Area includes the county of such a central city and adjacent counties as are found to be metropolitan in character and economically and socially integrated with the county and central city. Actually such an area might contain more than one city of 50,000 population, with the largest city considered the nucleus and is often the name given to the area. To have metropolitan character, at least seventy-five percent of the labor force of the county must be in nonagricultural labor.[6]

In the State of Michigan (as indicated in Appendix D), there were ten such designations. These included Ann Arbor, Bay City, Detroit, Flint, Grand Rapids, Jackson, Kalamazoo, Lansing, Muskegon — Muskegon Heights, and Saginaw. Ann Arbor is a designate for the City of Ann Arbor as well as Washtenaw County, with a population of 172,440. The Bay City area included Bay City, as well as Bay County, with a population of 107,042. The Detroit district included Macomb County, Oakland County, and Wayne County, as well as twenty-three major cities, with a total population of 3,762,360. The Flint area included the City of Flint, as well as Genesee and LaPeer Counties, with a total population of 416,239. Grand Rapids included the City of Grand Rapids, the City of Wyoming and Kent County, and Ottawa County for a total population of 461,906. Jackson included the City of Jackson, and Jackson County, with a population of 131,994. Kalamazoo included Kalamazoo County, and the City of Kalamazoo with a population of 169,712. The Lansing area encompassing Lansing and East Lansing, as well as Clinton County, Eaton County, and Ingham County had 298,949 persons. The Muskegon area included Muskegon and Muskegon Heights, and Muskegon County, for a total population of 149,943. And Saginaw, included the Saginaw City and the Saginaw County areas for a population of 190,752.[7]

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[5] *Standard Metropolitan Statistical Areas,* (Washington, D.C.: Office of Statistical Standards, 1964), pp. vii-viii.

[6] *Ibid.*

[7] *Standard Metropolitan Statistical Areas,* Executive Office of the President, Bureau of the Budget, Kermit Gordon, Director, Office of Statistical Standards, 1964, pp. 4-42.

Identification of Companies

Actual companies located in each statistical area had to be identified by size and product. Boards or Chambers of Commerce in each of the major cities involved were contacted and they furnished lists of companies, within their own areas, that employed 500 or more persons. From these reports, a master list of 205 companies was designated. These were then, the Michigan Manufacturing Companies located in the Standard Metropolitan Areas of Michigan and employing more than 500 persons that Task Force One considered, for the purpose of nominating companies to be invited to participate in the study. This list of Michigan companies appears in Appendix E.

Type of Industry

To increase the validity of the selection, Task Force One checked the type of industry, in the categories of construction, ferrous metals, nonferrous metals, fabricated metals, non-electrical machinery, electrical machinery, motor vehicles, chemicals, communications, utilities, engineering and architectural services, public administration, and miscellaneous. When it was noted by Task Force One that there was a lack of representation in some of these areas, it was suggested by the members of this group, that certain technical societies be approached for their recommendations for participation. Thus, The Engineering Society of Detroit, the National Association of Engineering Companies, the Detroit Tooling Association, The Association of General Contractors of America, the Builders Association of Metropolitan Detroit, and The American Institute of Architects were contacted relative to their use of technicians. Subsequently, it was determined that the builders associations and the general construction companies utilized apprentices, but not technicians as defined for this study; that architects associated with the American Institute of Architects did not involve technicians in their work. The tooling associations and engineering societies also indicated that they did not have a high usage of technicians. So the remaining technical societies accounted for the additions to the basic list. This had the added advantage of adding seven smaller firms to the study.

It was determined also by Task Force One that thirty-six of the listings were actually divisions of larger companies so they recommended that these smaller units be included in the interviews conducted at the corporation level. These companies were American Motors, Brunswick Corporation, Consumers Power Company, Chrysler Corporation, Ford Motor Company, General Motors Corporation, R. C. Mahon Company, and Michigan Consolidated Gas Company. The interviews in these companies were usually multiple, were at the corporation level, and reflected the results of composite consideration within the company.

Stratified Population

Thus 176 firms constituted the stratified population that was considered by Task Force One. Seventy-nine companies were actually selected for the study on the basis of "best practice" and "most promise" in their use of technicians. This constituted 44.8 percent of those which appeared in the listing in Appendix E. Fifty-two of the companies, or 25 percent were rejected by Task Force One because the type of product manufactured was not conducive to high technician involvement.

Once the companies were selected, letters, like the samples in Appendix B, were sent to top administrators seeking participation. The response (98.8 percent) was very favorable. Persons contacted were most cooperative in both the oral and written phases of the inquiry. It would be unfair to say that the others were uncooperative. Such reasons as "the company is moving," "a recent turnover of top personnel," and "company on strike" were given for nonparticipation. Due to decentralization, some of the larger companies required as many as ten separate interviews, while other companies were in a position to set up area conferences in which personnel from various parts of the company took part. In all of the larger companies, multiple personnel were involved in the interviews. Usually the president or personnel director in the smaller companies was in a position, by himself, or with the aid of one or two men, to provide the needed information. In all cases the checkoff lists were routed beyond the interviewees to persons closer to the actual technical occupation.

CHAPTER II

Presentation of Findings

Types of Technicians in Michigan Industry

The colorful era of the lumber jack and timber baron, in Michigan, ended in the 1800's due to the depletion of Michigan forests, but wood products are still manufactured in Bay City, Escanaba, Ludington, and Traverse City. Kalamazoo is known for its production of paper, but many of the wood raw materials are now imported. Thus, Michigan no longer depends upon timber as its prime natural resource, and companies, like Lufkin Rule in Saginaw, have survived by finding new products and markets. It was the timber resources, and transportation facilities, that originally drew the carriage works to the State. These were later converted to automobile plants. Now, over half of the industrial workers in Michigan are employed in the transportation industry.[1]

Workers in Michigan Industries

During the two world wars, the great automotive plants in Dearborn, Detroit, Flint, Kalamazoo, Lansing, and Pontiac manufactured guns, tanks, and other products for war. In 1966, the automotive industry is of major importance, but Michigan is a highly diversified industrial state. Just as Detroit is known as the automotive capital, Grand Rapids is famous for furniture production, Battle Creek is known for cereal, Midland and Ludington are great chemical producers, while Ann Arbor, Detroit, and Kalamazoo are world known for the drugs they manufacture. Cities like Detroit, Dowagiac, Hastings, and Saginaw rival other cities in the nation in the production of iron and steel. Michigan's industrial products include business machines, household appliances, and even ships. In 1960 there were 2,030,282 industrial workers in the ten standard metropolitan areas with 40 percent of them involved in manufacturing.[3]

TABLE 1
IDENTIFICATION OF MICHIGAN TECHNICIANS BY TYPE OF INDUSTRY[2]

Technicians Employed By Industries		*Number of Different Industries Surveyed*	
9961	motor vehicles	20	machinery
4035	machinery	15	motor vehicles
2715	ferrous & fab. metals	8	chemicals
1910	chemicals	5	electrical machinery
1328	construction	5	ferrous & fabricated metals
1070	electrical machinery	2	construction
462	non-ferrous metals	2	furniture
317	furniture	2	communication
1264	communication utilities miscellaneous	2	utilities
		1	non-ferrous metals
		9	miscellaneous
23062	**Total**	**71**	**Total**

The number of technicians used in Michigan industry in 1960, in rank order, is reported in Table 1. This has been compared to the number of companies, in each industry, that were surveyed. The plan was to make more frequent contacts in those industries that had the highest use of technicians. Although it might seem that fewer technicians were represented from the motor vehicles industry than the machinery industry, it must be remembered that companies representing the former were quite large.

In the communications and utilities industries there was indication of an emerging need for technicians, but in the printing industry it was found that the work was handled by the tradesman.

Types of Technicians in Study

Many technicians were found in Michigan industry but few companies actually use the word technician in the job title. Thus, these positions were identified primarily by the job description and educational prerequisites. Most employers were able to classify their workers after looking at the list of descriptive titles (reproduced in Appendix B).

TABLE 2
NUMBER OF TECHNICIANS SURVEYED BY TECHNOLOGIES

59	drafting
46	mechanical
38	laboratory
31	electrical & electronic
26	industrial
20	chemical
18	instrumentation
14	metallurgical
9	data processing
8	civil
5	fluid power
4	packaging
2	aeronautical
1	communications

When the mathematical checkoff lists were received, those job titles that had not been labeled by a technology were classified by reviewing remarks made in the recorded interviews. Table 2 is a listing of the technologies with an indication of the number of returns in each category. One of the telephone companies insisted that their technicians must properly be called communication technicians although another telephone company used the electronic technician classification. More often the broader classifications, such as mechanical instead of fluid power,

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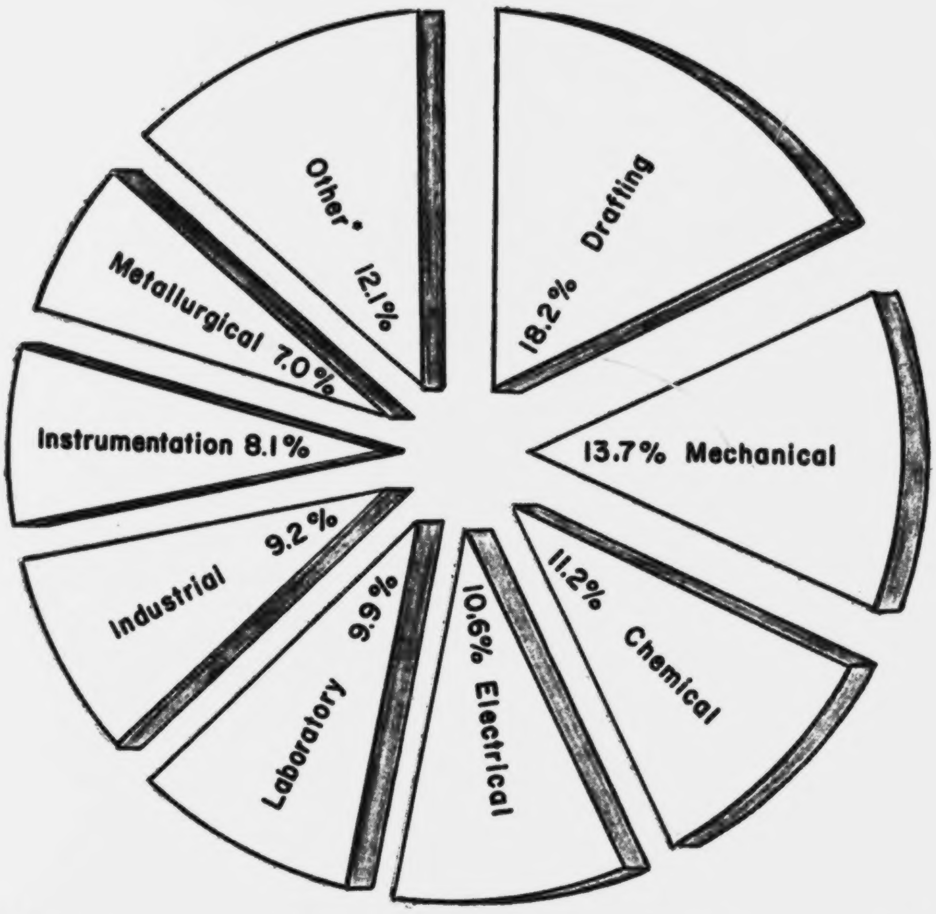
[1] U.S. Bureau of the Census, *U.S. Census of Population: 1960, Vol. 1, Characteristics of the Population, Part 24, Michigan,* (U.S. Government Printing Office, Washington, D.C., 1963), pp. 582-592.

[2] *Ibid.*

[3] *Ibid.*



*Data Processing	4.2%	Writer	1.3%	Fluid Power	1.6%	Aeronautical	0.6%
Civil	1.9%	Communication	0.6%	Packaging	1.6%	Biological	0.3%

FIG. 1 — TECHNICIANS SURVEYED

were used. The technology classification seemed to reflect the area of preparation more than the specific job assignment.

Figure 1 shows the relationship of the numbers of technicians surveyed in each technology by percentage. Although the investigation attempted to reflect the actual technologies in proportion to their usage, it may be noted that the seven major classifications represent a fairly even distribution.

Findings from the Interviews

Types of Personnel Interviewed

The chief administrative officer of each firm, as was mentioned, appointed the person or persons to be contacted. Tables 3 through 10 provide a summary of the interview responses made at seventy-one companies. This summary also represents many conference sessions and multiple interviews at individual companies. No weight factors were given (by size of company) since it did not appear that patterns developed according to size of company.

Of those interviewed (Table 3), 35 percent were managers, 18 percent presidents or vice-presidents, and 13 percent directors. Thus, 66 percent of those interviewed were at a high level of management. Personnel directors accounted for 15 percent, and researchers for another 6 percent of the contacts. Eleven percent were chief mechanics or engineers. All of these persons provided much essential data since they had a great deal to do with company policy in the use of technicians. Of the supervisors interviewed, 50.7 percent had been employed with the same company for more than fifteen years, while 42.2 percent had been in their present position for more than ten years (Table 4). Thirty-one percent of the supervisors were 46 to 50 years of age; only 11.2 percent were younger.

While 81.7 percent have college degrees (Table 5), 52.1 percent have only a bachelor's degree. Further, although only 59.2 percent graduated from colleges of engineering, 67.6 percent report (Table 6) having had calculus in their mathematical background.

Technician Evaluation by Supervisors

While almost every firm indicated that they would like to employ technicians who had completed two years of college work, 46 percent indicated that they had and were willing to accept high school graduation as a minimum educational requirement (Table 7). Thirty-five percent now require an associate degree, or equivalent, as a minimum educational requirement for their technicians. Private trade schools, service schools, and technical institutes provide the source of many of the present technicians. Some employers seek the two-year college dropouts, but often there appears to be a feeling that this type of person represents an engineer who is not fully qualified, as a technician. Many employers admit that they have used engineers to do work at the technician level.

Fifty-nine percent of those contacted were satisfied with their present technicians (Table 7) while

TABLE 3
POSITION AND YEARS WITH COMPANY

Industries Surveyed	Position With Company									Years With Company						
	President	Vice President	Manager	Director	Engineer	Master Mechanic	Personnel Director	Researcher	Other	0 To 5	6 To 10	11 To 15	16 To 20	21 To 25	26 Plus	No Answer
Machinery	3	2	7	2	2	1	2	1		1	3	4	5	4	2	1
Motor Vehicles		2	4	2	2	1	1	2	1	2		2	4	3	3	1
Chemicals			5		1		2			2	3			2	1	
Electrical Machinery			2	1			2			1	2	1			1	
Ferrous & Fab. Metals	1	1		2			1				1		2			2
Construction	2													1	1	
Furniture		1	1									1	1			
Communications			2									1		1		
Utilities			1	1			1						1	1		
Non-ferrous Metals			1										1			
Miscellaneous		1	2	1	1		2	1		2	2	1	1	1		1
Total	6	7	25	9	6	2	11	4	1	8	11	10	15	13	8	6
Percent	8.5	9.9	35.2	12.7	8.5	2.8	15.5	5.6	1.4	11.3	15.5	14.7	21.1	18.3	11.3	8.5

TABLE 4
YEARS IN POSITION AND AGE OF SUPERVISORS INTERVIEWED

Industries Surveyed	Years In Position							Age						
	0 To 5	6 To 10	11 To 15	16 To 20	21 To 25	25 Plus	No Answer	Less Than 30	31 To 40	41 To 45	46 To 50	51 To 65	66 Plus	Totals
Machinery	5	5	5	2	2		1	1		4	7	5	3	20
Motor Vehicles	3	2	4	3	1	1	1	1		2	5	4	3	15
Chemicals	6			1	1				2	2	1		3	8
Electrical Machinery	1	1	2			1				1	3	1		5
Ferrous & Fab. Metals		1		1		1	2	2				2	1	5
Construction		1				1						1	1	2
Furniture	1		1							1		1		2
Communications		1			1						1		1	2
Utilities	1		1				1	1		1	1	1		3
Non-ferrous Metals		1										1		1
Miscellaneous	4	2		1			1	1		2	4		1	8
Total	21	14	13	8	5	4	6	6	2	12	22	16	13	71
Percent	29.6	19.8	18.3	11.3	7.0	5.6	8.5	8.5	2.8	16.9	31.0	22.5	18.3	

TABLE 5

EDUCATIONAL BACKGROUND OF SUPERVISORS INTERVIEWED

Industries Surveyed	Type of College Attended						Major Field of Study						
	Large	Medium	Church	Ivy	Technical	No Answer	Liberal Arts	Professional	Business	Engineering	Education	Other	No Answer
Machinery	12	1	2	1	3	1	2		1	14	2		1
Motor Vehicles	6	3		2	3	1	1		1	11	1	1	
Chemicals	4	1		2	1		2	2		4			
Electrical Machinery	3	1			1				1	4			
Ferrous & Fab. Metals	2				1	2	2			1			2
Construction	1	1								2			
Furniture					2				1	1			
Communications	2									2			
Utilities	1		1			1	1		1				1
Non-ferrous Metals	1								1				
Miscellaneous		3			3	2		2		3			3
Total	32	10	3	5	14	7	8	4	6	42	3	1	7
Percent	45.1	14.1	4.2	7.0	19.7	9.9	11.3	5.6	8.5	59.2	4.2	1.4	9.9

TABLE 6

ACADEMIC STATUS AND MATHEMATICAL BACKGROUND OF SUPERVISORS INTERVIEWED

Industries Surveyed	Academic Status						Mathematics Background				
	Doctor's Degree	Master's Degree	Bachelor's Degree	Associate Degree	Certificate	No Answer	Calculus Plus	Calculus	Trigonometry	Algebra & Geometry	No Answer
Machinery		5	12		2	1	10	7	2	1	
Motor Vehicles	1	3	8		2	1	2	8	4	1	
Chemicals	2	4	2				4	2	1	1	
Electrical Machinery		1	3	1			1	2	1	1	
Ferrous & Fab. Metals			3			2	1	1	1		2
Construction		1	1				1	1			
Furniture			1	1				1		1	
Communications			2				1	1			
Utilities		1	1			1			2		1
Non-ferrous Metals		1						1			
Miscellaneous		2	4		1	1	1	3	2	1	1
Total	3	18	37	2	5	6	21	27	13	6	4
Percent	4.2	25.4	52.1	2.8	7.0	8.5	29.6	38.0	18.3	8.5	5.6

TABLE 7

EDUCATIONAL BACKGROUND OF TECHNICIANS ADVOCATED BY SUPERVISORS INTERVIEWED

Industries Surveyed	Educational Background					Mathematical Background					
	High School	Tech. Inst.	Jr. College	Col. Dropout	Company School	Sufficient Mathematics	Need More Application	Arithmetic Weak	Algebra Weak	Trigonometry Weak	Calculus Needed
Machinery	9	5	6			12	8				
Motor Vehicles	6		7		2	10	5				
Chemicals	4		4			5	1			1	1
Electrical Machinery	2	2	1			4	1				
Ferrous & Fab. Metals	1	1	3			3	2				
Construction	1			1		1	1				
Furniture			1		1	1				1	
Communications	2						1		1		
Utilities	1		2			2	1				
Non-ferrous Metals	1					1					
Miscellaneous	6	1	1			3	2	1		2	
Total	33	9	25	1	3	42	22	1	1	4	1
Percent	46.5	12.7	35.2	1.4	4.2	59.2	31.0	1.4	1.4	5.6	1.4

TABLE 8

MATHEMATICAL SKILLS OF TECHNICIANS ADVOCATED BY SUPERVISORS INTERVIEWED

Industries Surveyed	Mathematical Emphasis			Calculator Skill		Slide Rule Skill		Computer Skill			Requirements In Ten Years	
	Practical	Abstract	Thinking	Yes	No	Yes	No	Yes	No	No Answer	Same	Increase
Machinery	13	3	2	7	13	19	1	9	7	4	7	13
Motor Vehicles	14		1	7	8	15		7	4	4	5	10
Chemicals	8			7	1	7	1	3	5		3	5
Electrical Machinery	4		5	3	2	5		3	1	1	1	4
Ferrous & Fab. Metals	4	1		3	2	5		3	1	1	2	3
Construction	2				2	2			1	1	2	
Furniture	1		1		2	2		1		1	1	1
Communications	2			2		2		2			1	1
Utilities	2			2	1	3		1	2			3
Non-ferrous Metals	1				1	1		1			1	1
Miscellaneous	6	1	1	2	6	8		4		4	2	6
Total	57	5	10	33	38	69	2	34	21	16	25	47
Percent	79.2	6.9	13.9	46.5	53.5	97.2	2.8	48.0	29.5	22.5	34.8	65.2

TABLE 9

BASIC MATHEMATICS FOR TECHNICIANS ADVOCATED BY SUPERVISORS INTERVIEWED

Industries Surveyed	Basic Mathematics Needed					Mathematical Ability Compared to Engineers		Math. Skill Qualifications For Employment			
	Arithmetic	Algebra	Geometry	Trigonometry	Calculus	Less	More Practical	Initial Needs	Growth Ability	Total Needs	No Answer
Machinery		1	2	17		18	2	6	13	1	
Motor Vehicles	2		1	12		15		3	11		1
Chemicals		1		6	1	8		1	7		
Electrical Machinery		1		4		5		5			
Ferrous & Fab. Metals	1			4		5		2	3		
Construction				2		2		2			
Furniture				2		2		1	1		
Communications	1			1		1	1	1		1	
Utilities				3		3			3		
Non-ferrous Metals				1		1			1		
Miscellaneous		3		5		8		3	5		
Total	4	6	3	57	1	68	3	24	44	2	1
Percent	5.6	8.5	4.2	80.3	1.4	95.8	4.2	33.8	62.0	2.8	1.4

TABLE 10

CONTINUED MATHEMATICAL DEVELOPMENT ADVOCATED BY SUPERVISORS INTERVIEWED

Industries Surveyed	Additional Mathematical Skills Needed					Continued Formal Schooling			
	Gearing	Mobility	Statistics	Calculus	Practical	Local or Jr. College	Company Sponsored or Taught Classes	None	No Answer
Machinery	2		1			19		1	
Motor Vehicles		1	3			13		2	
Chemicals						8			
Electrical Machinery				1		4			1
Ferrous & Fab. Metals						4		1	
Construction								2	
Furniture					1	2			
Communications				1		1	1		
Utilities	1			1		3			
Non-ferrous Metals						1			
Miscellaneous			1			7	1		
Total	3	1	5	3	1	62	2	6	1
Percent						87.3	2.8	8.5	1.4

31.0 percent felt that their background in mathematics should have been more practical. This idea was followed by a strong recommendation by 79.2 percent (Table 8) that practical mathematics receive more emphasis in technical mathematics curriculums. Forty-six percent listed calculator skills, 97.2 percent slide rule skills, and 48 percent computer skills as useful for technicians. Sixty-five percent predicted an increased mathematical need for technicians in the next ten years.

Mathematical ability through trigonometry for technicians was suggested by 80.3 percent of the supervisors (Table 9). Almost all (95.8 percent) agreed that the technician needs less mathematics than the engineer, but 4.2 percent emphasized that the technician needs a more practical mathematics. While 33.8 percent of the supervisors expected the technician to know his mathematics before being employed, 62 percent recognized that the application phase of the technician work would provide for growth in mathematical ability. It was encouraging to note that 87.3 percent of companies involved in the study had plans that encourage employees to continue their education (Table 10).

Figure 2 indicates in percentages the amount of mathematics that supervisors in various industries feel that their technicians should have. The center pie of Figure 2 is a summary of the individual categories and clearly shows that trigonometry is the most advanced course advocated.

The Mathematical Checkoff Lists

All Technicians

The items on the mathematical checkoff lists returned were compared (by technician type, and by industry type) to determine areas of agreement and disagreement. These comparisons are reported in Figure 3, in terms of percent of response in categories of **essential, desirable,** and **not needed.**

Although some of the mathematical fundamental skills are more important than others, Table 11 shows that the fundamental operations of arithmetic, common and decimal fractions, significant figures, standard notation, ratio and proportion, and use of tables were the most basic skills needed. Weight and measurement conversions, multiplication and division on the slide rule, measurement, and micrometer reading were considered important, but few technicians need the machinist mathematical skills of indexing, gear ratio, thread and screw formulas. Also, few felt that the ability to use the slide rule to solve problems of powers, roots, and percentage was essential.

Basic algebra from the concept of real numbers, the four fundamental operations, signs of aggregation, absolute values, ratio, proportion, and fractions, factoring through linear equations was considered essential for technicians. But inequalities, functions, systems of equations and graphic representation seemed only desirable while determinants, high order equations and other advanced topics were rated as not needed.

Basic figures and geometric facts about lines, angles, and planes were the only fundamentals that received an essential rating. Other geometric concepts were listed as desirable but interestingly, the mensuration formulas were rated as not needed by many. Analytical coordinate geometry was also judged as not needed.

There was a strong indicated need for right triangle trigonometry. Topics dealing with angles, functions, and tables were considered essential, but the solution of oblique triangles and analytical trigonometry was considered only desirable.

No calculus skills were considered important to the work of the technician. Few topics in the area even received a desirable classification and most were marked as not needed.

Unexpectedly, the ability to use a calculating machine was considered a desirable skill for a technician.

Mathematical Fundamentals by Technologies

In addition to a comparison of the mathematical fundamentals needed by all technicians, as shown in Figure 3, it seemed desirable to compare these fundamentals by technologies. The essential, desirable, and not needed responses by technicians have been summarized in Appendix A. In many responses there was almost total agreement but some interesting exceptions were noted.

While logarithms (at least common logarithms) were rated as desirable for most technicians — industrial, laboratory, mechanical, and packaging technicians indicated that logarithms (of any kind) were not needed. Only the aeronautical, drafting, mechanical, and fluid power technicians felt that mathematics dealing with threads and gears was essential.

Some types of technicians deal basically with arithmetic calculations and simple algebra including linear equations. Thus, chemical, industrial, instrumentation, laboratory, mechanical, and metallurgical technicians rated few algebraic topics as essential. The drafting, electrical, packaging, fluid power, and communication technicians decided that systems of equations and quadratic equations were essential fundamentals. Only the aeronautical and data processing technicians rated the most advanced algebraic topics as essential.

Civil, drafting, electrical, fluid power, and construction technicians were the only ones to give emphasis to more than the very basic elements of geometry. The metallurgical technicians, especially, had no need for the mensuration formulas.

Beyond right triangle trigonometry, civil, drafting, and mechanical technicians ranked the solution of oblique triangles as essential but only aeronautical, drafting, mechanical, laboratory, metallurgical, and civil technicians, rated analytical trigonometry as even desirable.

Aeronautical, data processing, electrical, and packaging technicians indicated that some practical calculus would be desirable. As would be expected, data processing technicians indicated that knowledge of analog and digital computers was essential for them, but only aeronautical, chemical, civil, electrical, packaging, fluid power and communication technicians even classified them as desirable skills.

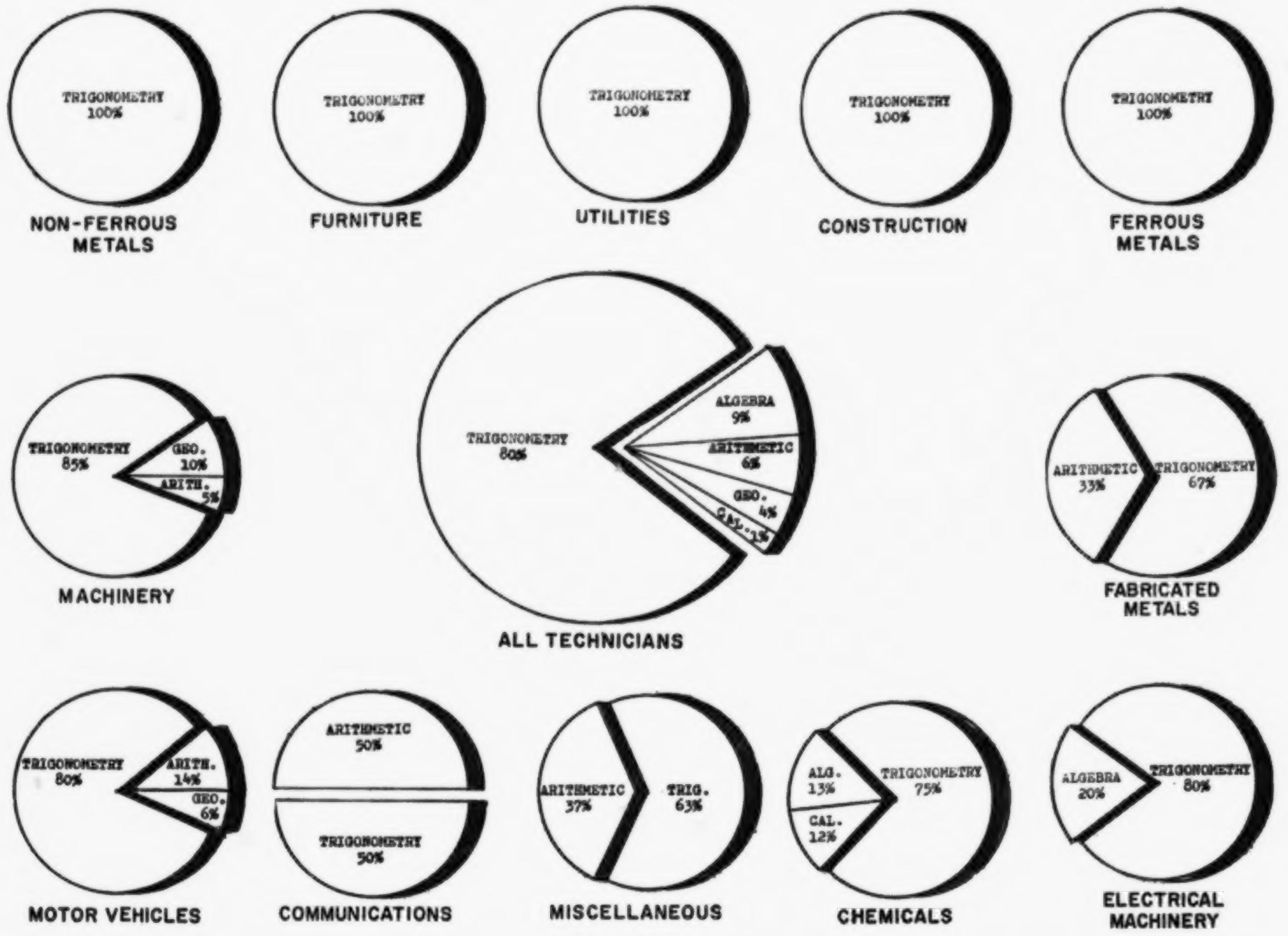


FIG. 2 — NEEDED MATHEMATICAL SUBJECTS AS REPORTED BY SUPERVISORS IN MAJOR MICHIGAN INDUSTRIES

Mathematical Fundamentals by Type of Industry

A comparison of the mathematical needs of technicians can be made according to the type of industry involved. This comparison provided a greater variety in the responses. Even in the section dealing with arithmetic skills there was found a difference in importance when this type of comparison was made. Appendix A shows that technicians in construction, electrical machinery, furniture, and fabricated metals industries require less arithmetic skills than those in ferrous metals, non-ferrous metals and communications. Except for a lack of demand for plain and differential indexing, complex gear ratio, lead screws, and natural logarithms, the arithmetic fundamental skills were deemed desirable for all. The desirable, rather than essential, classification was most frequently indicated for percent, interest, and common logarithms, especially as calculated on the slide rule.

Although the more elementary topics of algebra were listed as desirable, technicians in construction and furniture industries indicated no need for this subject. Even technicians in fabricated metals, and electrical machinery industries showed a limited need for algebra by rating content through simple equations and formulas as important, and the more advanced skills as only desirable. But the other industries including ferrous metals, motor vehicles, and communications, listed algebra fundamentals as essential —at least through quadratic equations.

In geometry the pattern changed some. Technicians in non-ferrous metals and electrical machinery industries needed less skill in this subject, while technicians in construction, motor vehicles, utilities, and communications industries listed more geometric fundamentals, as essential.

Trigonometry was judged as not needed by technicians in the non-ferrous metals, electrical machinery, and furniture industries, but at least desirable by most, and essential for construction, ferrous metals, and utilities. An understanding of right triangle trigonometry was felt as essential, or desirable, by all — but the demand for oblique triangle trigonometry and analytical trigonometry was limited to construction, ferrous metals, and utilities industries.

No calculus was suggested as essential, but technicians in fabricated metals and communications industries indicated that basic calculus skills were desirable.

Among technicians in construction, motor vehicles, communications, and utilities industries, the analog and digital computer language skills were judged desirable. All but electrical machinery rated calculating machine skills as desirable and fabricated metals, chemical, and the furniture industry rated these skills as essential.

TABLE 11 — MATHEMATICAL FUNDAMENTALS BY RANK ORDER

Arithmetic Skills

Essential:

Fundamental Operations (addition, subtraction, multiplication)
Fractions, Common and Decimal
Standard Notation and Significant Figure
Measuring (rule, micrometer, vernier)
Tables and Interpolation
Ratio and Proportion
Conversions (weights and measure) (English and Metric)
Approximation and Estimation
Slide Rule, Multiplication and Div.
Slide Rule, Ratio and Proportion
Percentage and Interest

Desirable:

Common Logarithms
Slide Rule, Powers and Roots
Slide Rule, Percent and Interest
Slide Rule, Common Logarithms

Not Needed:

Natural Logarithms
Slide Rule, Natural Logarithms
Gears and Gear Ratio
Screw Threads and Spirals
Plain and Differential Indexing
Complex Gear Ratio and Lead Screw

Calculus Skills

Not Needed:

Variables, Functions
Limits
Basic Theorems
Integration
Differentiation
Integration Formulas
Methods of Integration
Polar Coordinates
Infinite Series
Vector Analysis
Parametric Equations
Trancendental Functions
Differential Equations
Partial Differentiation
Hyperbolic Functions
Slide Rule, Hyperbolic Functions
Multiple Integrals

Algebraic Skills

Essential:

Fundamental Operations with Literal Numbers (addition, subtraction, multiplication)
Ratio, Proportion, Variation
Fractions, Fundamental Operations
Formulas and Linear Equations
Signs of Aggregation (parentheses etc.)
Explicit and Literal Numbers
Absolute Values
Symbolic Expressions

Desirable:

Complex Fractions
Factoring and Special Products
Use of Functions and Relations
Inequalities
Graphical Representation of Equations
Quadratic Equations
Systems of Equations

Not Needed:

Progressions, Arithmetic
Exponential Equations
Progressions, Geometric
Vector Algebra
Determinants
Synthetic Division
Equations of Any Power
Complex Numbers
Higher Order Equations
Binominal Theorem
Number Theory

Additional Mathematical Skills

Essential:

Operation of Calculating Machines

Not Needed:

Probability
Applied Statistics and Dynamics
Analog and Digital Computers
Curve Fitting
Vector Analysis
Logic Systems
Root Approximation and Identification
Boolean Algebra
Set Theory

Geometric Skills

Essential:

Basic Geometric Figure Concepts
Lines, Angles, Planes

Desirable:

Congruence
Polar Coordinate Functions
Similarity
Constructions
Parallelism in Lines and Planes

Not Needed:

Locus
Inequalities
Mensuration, Plane
Mensuration, Solid
Coordinate Geometry (analytic)
Methods of Proof and Reasoning

Trigonometric Skills

Essential:

Angles and Coordinates
Trigonometric Tables
Trigonometric Functions
Right Triangles, Trigonometric Solution of

Desirable:

Slide Rule, Trigonometric Functions

Not Needed:

Oblique Triangles, Solution of
Trigonometric Functions by Arc Length Method
Trigonometric Functions by Unity Method
Plane Vectors
Periodic Functions
Graphs of Trigonometric Functions
Analytical Trigonometry, Formulas
Analytical Trigonometry, Equations
Analytical Trigonometry, Identities
Complex Numbers
DeMoivre's Theorem

Fig.3.--Mathematical Fundamentals For All Technicians

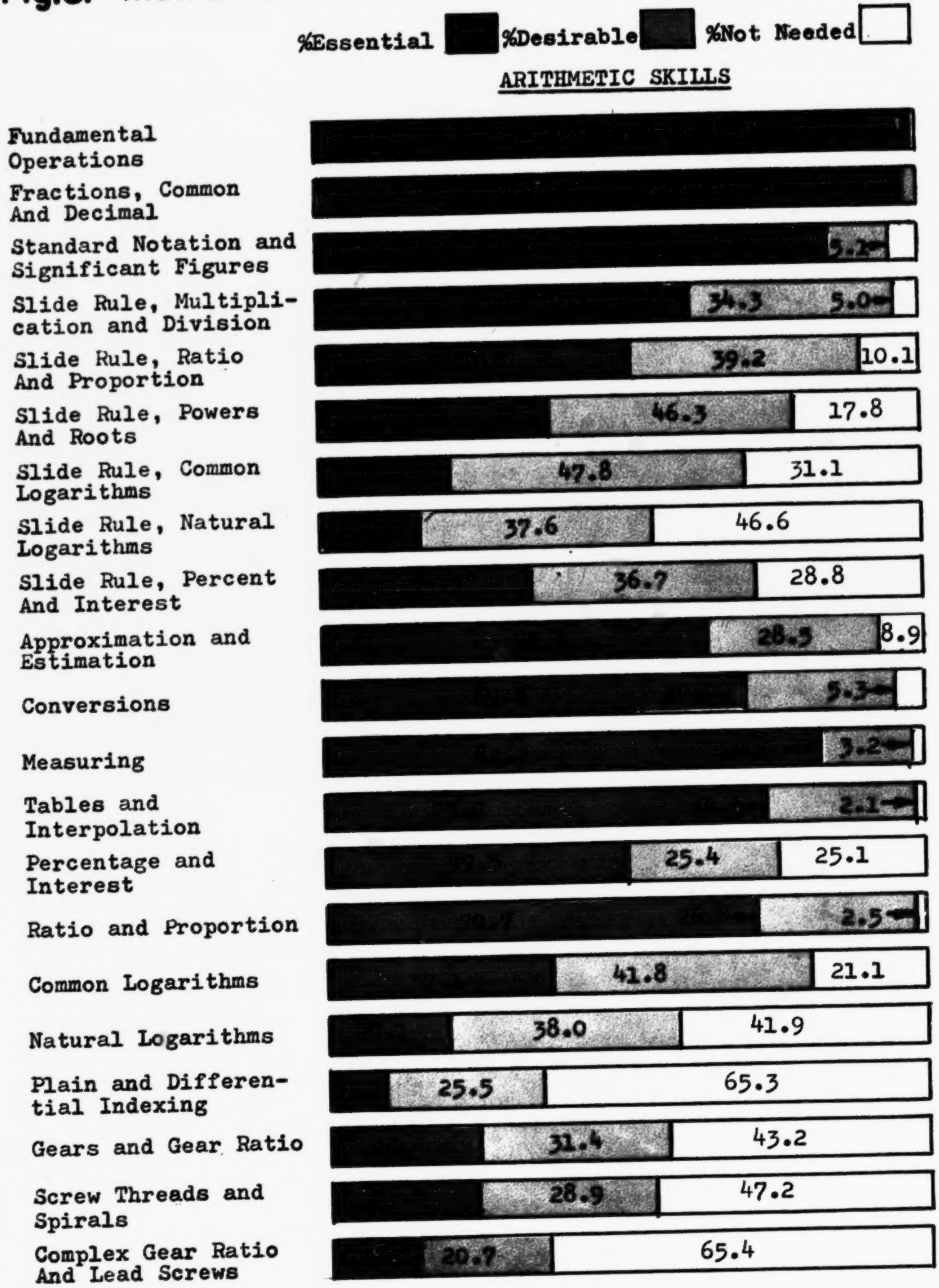


Fig. 3.--Continued

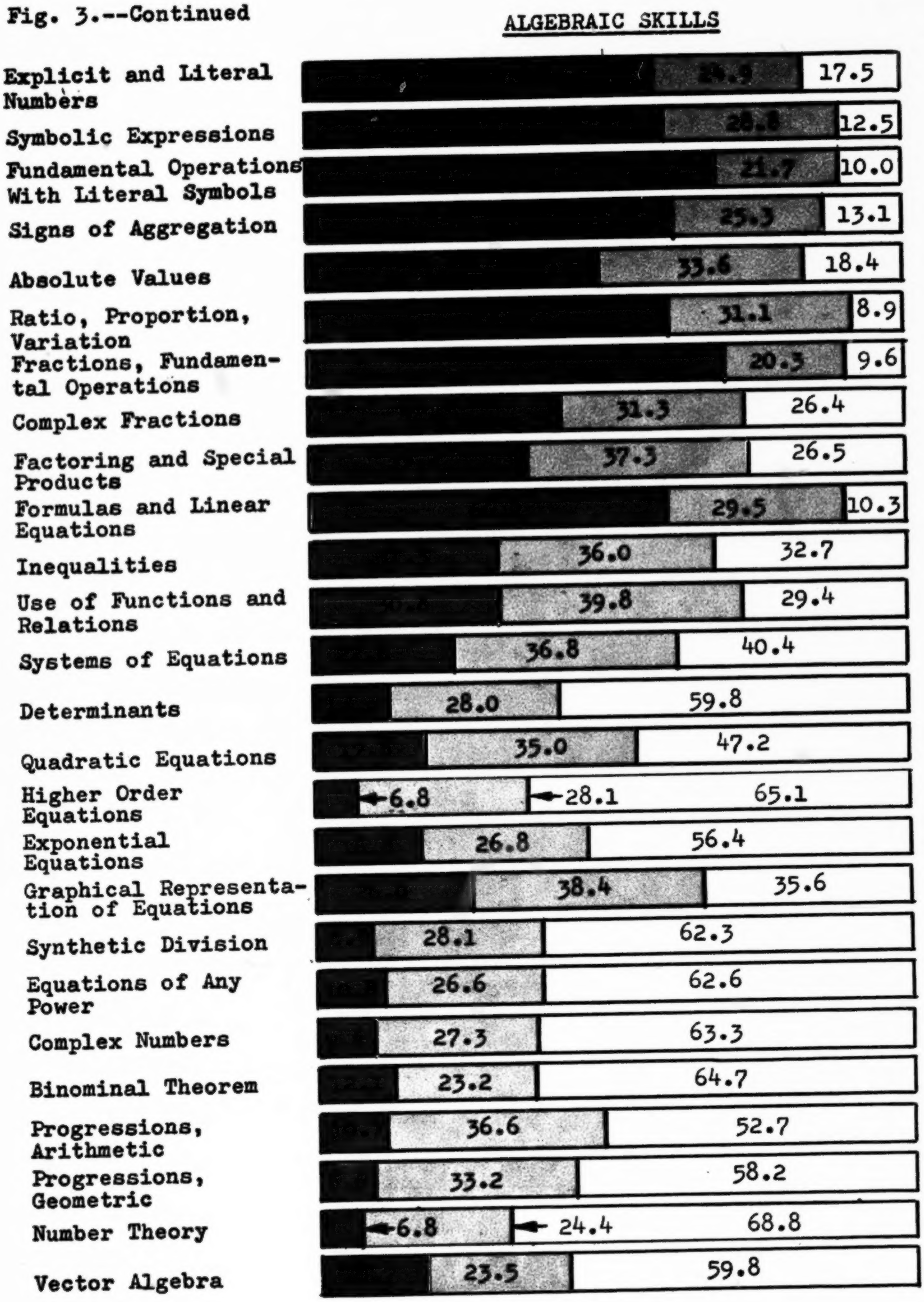


Fig. 3.--Continued

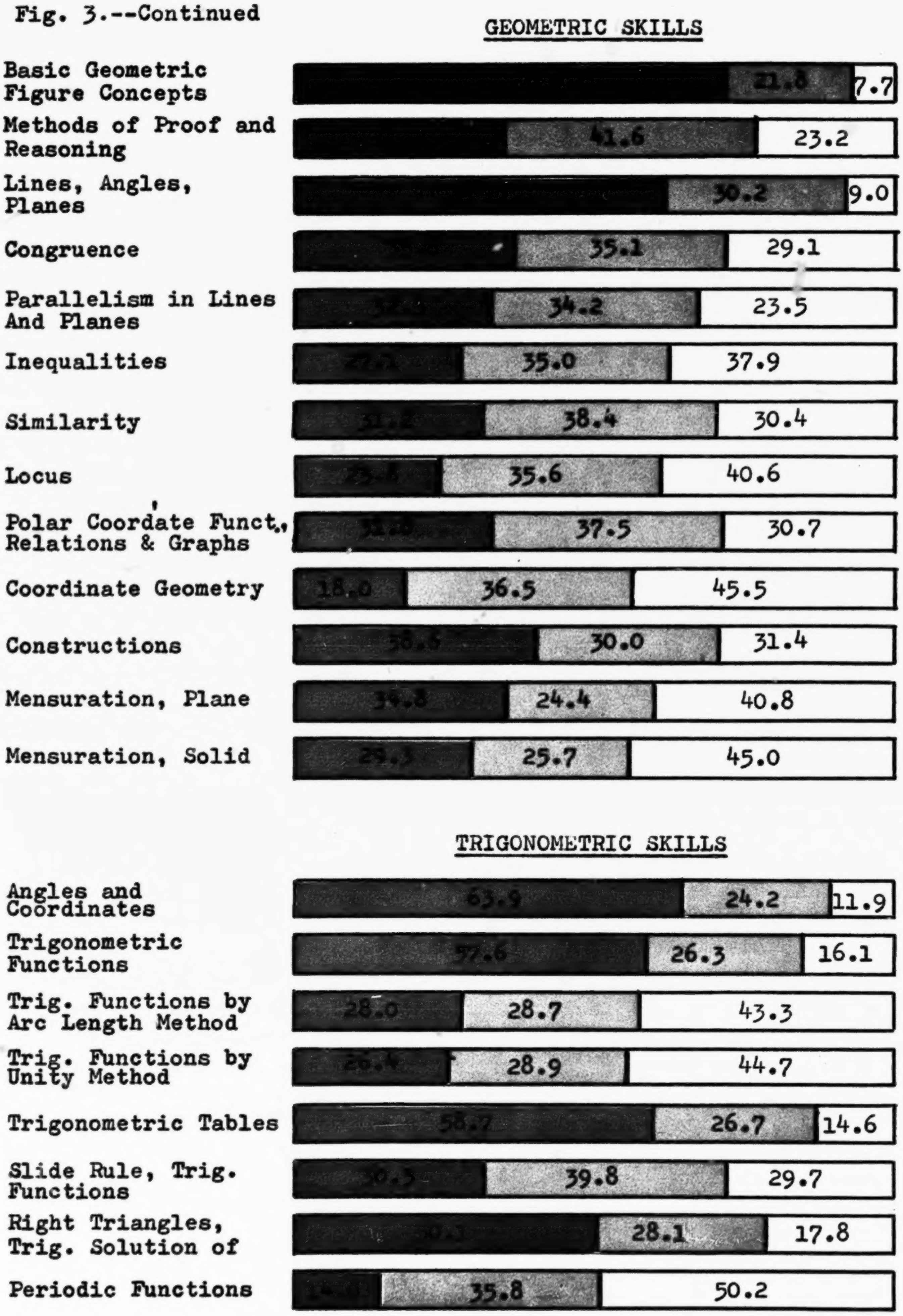


Fig. 3.--Continued

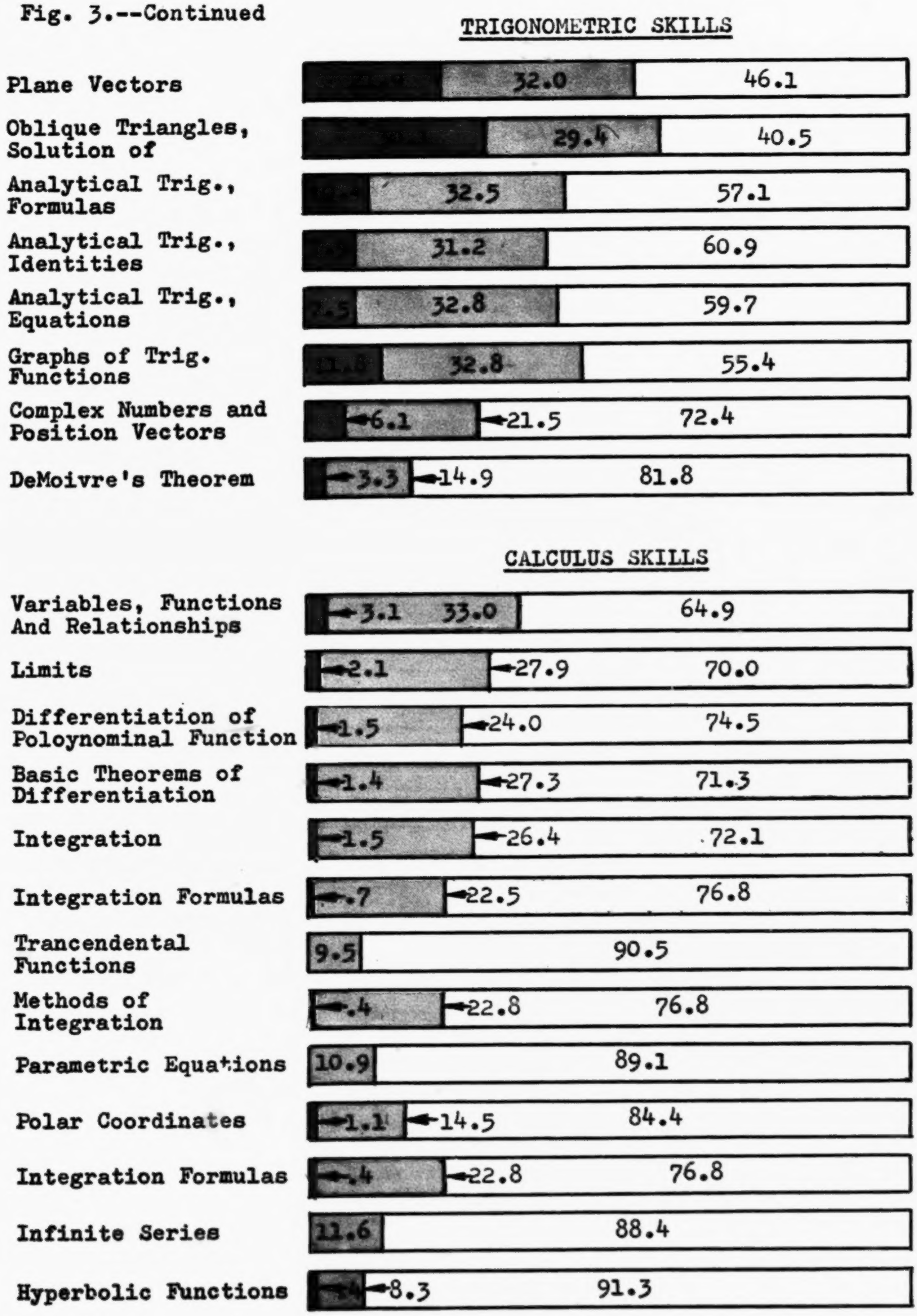
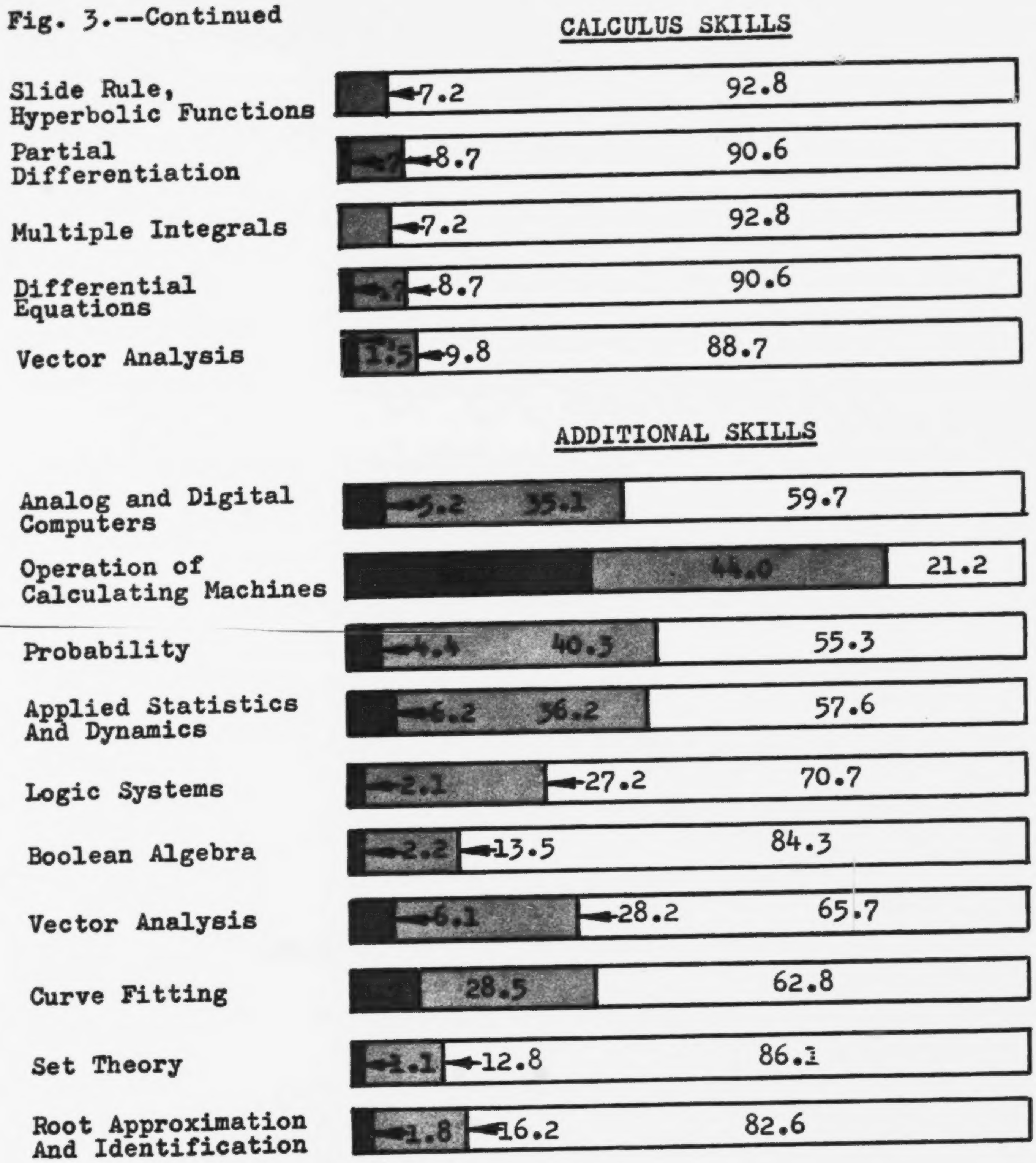


Fig. 3.--Continued



Mathematical Fundamentals by Subjects

The frequency rating of topics as essential, desirable, and not needed (for the subject categories of arithmetic, algebra, geometry, trigonometry, and calculus as summarized in Figure 3) shows which fundamentals were deemed essential. It also gives an indication of topics that were not important to the mathematical qualifications of technicians.

In arithmetic, those skills that were rated most important were: fundamental operations, fractions, standard notation, significant figures, approximation, estimation, conversions, measures, tables, ratio, and proportion. Logarithms, indexing, gears, gear ratio, screw threads, spirals, complex gear ratio, and lead screws were all rated low.

In algebra the fundamental operations, ratio, proportion, variation, fractions, and equations all rated high. The advanced topics were not deemed essential.

Basic figures, lines and angles were considered important in geometry, but other topics fell only into the desirable range.

Right triangle trigonometry, including basic angles, functions, and tables were rated essential. Analytical trigonometry was not considered essential.

CHAPTER III

Summary, Conclusions, Observations and Recommendations

The summary presents the procedural highlights of the investigation. These are followed, in answer to the objectives stated on page one, by the conclusions of the study. In addition, the researcher assumes the prerogative of making some additional clearly related observations. Also, he presents his predictions of future mathematical needs of technicians in Michigan, and finally a list of recommended mathematical fundamentals.

Summary of the Study

Technician Needs

Michigan, like other industrial states in America, has a labor shortage and a labor surplus. The surplus is among the unskilled workers and the shortage is among the skilled workers, especially in the technician classification. With increased automation and technological advance in industry, the technician is one of the most sought workers. It has been estimated that from 695,000 to 803,300 new technicians should be readied yearly for the labor market. The five thousand technicians being graduated annually from post-high-school programs are not enough to fill the needs of industry.

Mathematical Needs

Basic to the education of any technician is knowledge and skill in the fields of mathematics and science —and an understanding of mathematics is required to understand science. Thus, as educators are faced with the problem of supplying more and more technician graduates, it seemed important to examine the mathematical needs of technicians.

There was little evidence that such a detailed investigation had been attempted and it was suspected that current recommendations of mathematics for technical curriculums had been based on a scaled-down version of the mathematical requirements of the engineer. If the student acquires too little mathematical skill, he will not be able to function as a technician. But, if the mathematical requirements are unrealistic, many prospective technical workers will fail to qualify and the surplus of unskilled workers and shortage of skilled workers will continue.

Selection of Population

A Task Force of selected leaders in business, education, government, and industry in Michigan was called upon to select the Michigan companies to be involved in the study. For the most part, larger firms were chosen, on the basis of their known leadership in the use of technicians. Local Chambers of Commerce furnished the names of over 200 firms located in the Standard Metropolitan Statistical Areas of the State and that employed more than 500 persons. The Task Force added seven smaller firms and consolidated 36 previously named firms by designating contacts at the corporation level. Some firms were deleted as not suitable for the inquiry. Finally, 79 firms were selected which was 44.8 percent of those that qualified. Of this number, 71 (89.9 percent) were interviewed.

Interviews

Management personnel, as directed by the top administrative officer of the company, were interviewed. In some of the smaller companies, one or two persons participated, but in the larger firms the interview was in the form of a series of contacts with various persons, or was handled by a conference style interview. A tape recorder was used, together with a set of prepared questions, to determine management views of the mathematical needs of their technicians. The interview served also to identify the types of technicians that were employed by each company. The use of a recorder expedited the interviews and gave the researcher an opportunity to study the responses thoroughly.

Mathematical Checkoff Lists

The researcher supplied mathematical checkoff lists for each major technician category that had been identified in the interview and requested that they be routed to senior technicians. In the 71 companies contacted, 66 (91.7 percent) completed and returned the mathematical checkoff lists. These were processed through the Wayne State University Computer Center so that the data could be analyzed.

Source of Technical Personnel

It was learned that 46.5 percent of the technicians now employed in Michigan firms have no more than a high school education. When possible, employers prefer graduates of community colleges, armed forces schools, or technical institutions. Some look for engineering school or other four-year college dropouts. In 87.3 percent of the firms contacted, company policy provides for a tuition subsidy to their workers to encourage further study.

Basic Mathematics Needed

All felt that the technician should work under the supervision of the scientist or engineer whose mathematical background is more complete but a few (4.2 percent) thought that the mathematics used by the technician was more practical than that used by engineers. Eighty percent of those visited felt that the technician needed a good working knowledge of arithmetic, manipulative ability in algebra (especially equations), a knowledge of geometric figures, and an understanding of right-triangle trigonometry. A few companies (5.6 percent) felt that their technicians needed only arithmetic. The slide rule was described as a useful tool by 97.2 percent, while 46.5 percent felt that the technician should also be able to use a calculator.

Although employers seek persons who have a workable knowledge of trigonometry, and perhaps some understanding of practical calculus, the emphasis is on their ability to accurately make arithmetical and algebraic calculations of practical problems, and to understand the reasonableness of their solutions.

Conclusions of the Study

Mathematical Need by Technologies

The mathematical checkoff lists filled out by technicians were in agreement with the information obtained by interviewing supervisory personnel. Although they both indicated the amount of mathematics needed by the technician in Michigan industry, the checkoff list gave greater detail.

Although more advanced subjects seem to lend glamor, only arithmetic, algebra, and trigonometry were considered essential. Such topics as indexing, gears, threads, and complex gears were not necessary for most technicians. Even logarithms were not needed. Advanced algebra skills, past quadratic equations, were rated only as desirable for some while others felt that up to theory of equations the items in the checkoff list were essential. Right-triangle trigonometry was rated as desirable but few felt that oblique triangle trigonometry was essential and the analytical trigonometry and calculus were not considered essential.

Common Core

It was established that skills in arithmetic, algebra, geometry, and trigonometry (through right-triangles) were needed by all classifications of technicians. Returns further indicated that technicians in aeronautical, civil, drafting, electrical, fluid power, and construction industries needed some trigonometric instruction beyond this core. The same type of technician worked at a different technician level at different companies, but the basic mathematical fundamentals were needed by all technicians.

Mathematical Qualifications

Twenty-seven percent of the supervisors contacted felt that a technician should be well prepared in

TABLE 12 — RECOMMENDED MATHEMATICAL FUNDAMENTALS FOR CURRICULUMS TO PREPARE TECHNICIANS

Arithmetic Skills

Fundamental Operations
(addition, subtraction, multiplication, division)
Fractions, Common and Decimal
Ratio and Proportion
Tables and Interpolation
Approximation and Estimation
Standard Notation and Significant Figures
Slide Rule, Multiplication and Division
Slide Rule, Ratio and Proportion
Conversions (weights and measure)
(English and Metric)
Measuring (rule, micrometer, vernier)
Percentage and Interest
Slide Rule, Percent and Interest
Slide Rule, Powers and Roots
Common Logarithms
Slide Rule, Common Logarithms

Trigonometric Skills

Angles and Coordinates
Trigonometric Functions
Trigonometric Functions by Unity Method
Trigonometric Tables
Slide Rule, Trigonometric Functions
Right Triangles, Solution of
Oblique Triangles, Solution of
Analytical Trigonometry, Formulas
Analytical Trigonometry, Identities
Graphs of Trigonometric Functions
Complex Numbers and Position Vectors

Algebraic Skills

Explicit and Literal Numbers
Symbolic Expressions
Fundamental Operations with Literal Symbols
(addition, subtraction, multiplication, division)
Signs of Aggregation (parentheses, etc.)
Absolute Values
Ratio, Proportion, Variation
Fractions, Fundamental Operations
Complex Fractions
Factoring and Special Products
Formulas and Linear Equations
Inequalities
Use of Functions and Relations
Systems of Equations
Determinants
Quadratic Equations
Higher Order Equations
Exponential Equations
Graphical Representation of Equations
Synthetic Division
Equations of Any Power
Complex Numbers

Geometric Skills

Basic Geometric Figure Concepts
Constructions
Lines, Angles, Planes
Congruence
Parallelism in Lines and Planes
Similarity
Mensuration, Plane
Mensuration, Solid
Coordinate Geometry (analytic)

mathematics prior to employment, to the extent that he would receive little mathematical instruction on the job. Only 2.8 percent of the companies offered their own instructional classes to improve employee skills and only a few were concerned with mathematics. Eighty-seven percent of the companies contacted, however, had tuition subsidy plans, to encourage employees to attend local colleges. But 69 percent allowed that some growth, especially breadth in application, should take place. It was predicted by 65 percent that, in the next decade (by 1977), additional topics concerned with statistics and, computer language would become essential and that many technicians would need a practical knowledge of calculus.

Researcher's Observations

Type of Technician

Technicians in Michigan's industries, according to the Engineer's Council for Professional Development, should probably be called industrial technicians. There is little evidence that engineering technicians are being utilized in Michigan industry. Perhaps this is an indication of the stage of development of the technician concept in Michigan's industries, and perhaps is related to the lack of accredited Engineering Council for Professional Development programs in the State.

Sources of Technicians

There appears to be little importing of technician graduates from outstate educational institutions, and as long as the employers' demand is at the industrial technician level, the qualifications, as they particularly relate to mathematical competence, will be those needed by industrial technicians.

Problem Solving Approach

A common core of needed mathematical fundamentals has been identifiable for Michigan's technicians but a listing of these fundamentals is not sufficient. Employers are interested in workers who understand problem solving. It is suggested, therefore, that the instructor in a technical mathematical course needs to be concerned also with accurate solutions to realistic practical applications. To illustrate, throughout the courses, the student should be allowed to use his slide rule, as he would on the job.

Teacher Qualifications

Ability to cope with mathematical concepts alone is not enough to qualify a person to teach mathematics to technical students. Perhaps the best type of teacher is one who, in addition to his mathematical competence, has had practical industrial work experience.

It is preferred that the mathematics teacher have at least a master's degree in mathematics or a major in mathematics. More essential than advanced courses in mathematics is past experience in industry, that provides the teacher insights into the technician's problems. Mathematics at this level, must seem relative and realistic to the student, and prepare him functionally to do the type of calculations that are required of technicians.

Recommendations for Implementation of the Findings

A Basic Technical Mathematics Curriculum

On the basis of the responses, recommendations to be considered for a technical mathematics curriculum for technicians in Michigan are summarized in Table 12. The items are listed in order of importance.

Pedagogically, other fundamentals not rated as needed might be included, but the teacher should not be bound by tradition. It is suggested that many "advanced" topics (such as higher order equations) could be introduced without the usual intervening material. In the recommendation, no topic is meant to be excluded if the teacher, on the basis of his students' needs, can justify its existence. On the other hand, many topics, such as logarithms to various bases, are frequently included in a mathematical curriculum for the sake of completeness, even if they are useless to the technical student. This should be guarded against.

Choosing a Text

The selection of a suitable text for technical mathematics is of prime importance. Students lose confidence if the books are plagued with errors, both in the subject content and problem solutions. While several publishing companies have introduced new technical mathematics books, in recent years, the selection of an adequate and reliable text is important. Some "so called" technical books are merely topical collections of traditional mathematical materials. The teacher must be cautioned to determine the course content first, and then select the text rather than allowing the subject organization of the text to dictate course content.

Philosophy of the Technical Mathematics Teacher

The teacher of technical mathematics must be committed to the technician philosophy — preparing young men, including those with only average ability to cope with abstract ideas, to fill highly important positions with engineering teams in industry. This involves teaching courses that are designed to be utilitarian and highly practical in preparing the student for his vocation.

It is desirable that the teacher visit industry from time to time to observe the work of technicians and, when practical, to periodically take a work assignment. The teacher of technicians must be aware of up-to-date processes and technological advancements.

The effective teacher must be able to stimulate and motivate his students. Mathematics must be made interesting and important. Effective learning aids that draw and hold student interest must be developed. For the technical student, the lecture method does not seem to be as effective as demonstrations, visual presentations, discussions, and student-directed performances. Testing should be used as a learning aid as well as an evaluation device. Regular homework assignments are necessary to minimize time spent in class on drill that can better be utilized in clarifying and reviewing concepts. The conscientious teacher will motivate his students to accomplish the homework only if he is willing to spend many hours reviewing students' work. Graded homework not only emphasizes self study but helps the student to learn from his mistakes and guides the teacher in determining class needs.

Future Needs

It would seem reasonable to expect that the mathematical needs of Michigan technicians will increase and that many of the fundamentals now listed as desirable could later become essential. In the years ahead, more will be required of the technician in computer and statistical language, and perhaps a new mathematical language may become essential to the technician. As Michigan industries increase their use of technicians and as more technicians are used as "engineering technicians", it seems obvious that mathematical needs will increase sharply.

APPENDIX A

Comparison of Mathematical Fundamentals

Appendix A is a summary of the responses to the Mathematical Checkoff List which is included in Appendix B. Responses in the categories of (1) Essential, (2) Desirable, and (3) Not Needed are represented in percentages.

Figure 4 is a comparison, for each mathematical fundamental, of the response from the eight most frequently identified technologies, which represents 90 percent of the technicians surveyed.

Figure 5 is a comparison, for each mathematical fundamental, of the response from the eight most frequently identified industries, which represents 94.5 percent of the technicians in Michigan.

APPENDIX A

MATHEMATICAL FUNDAMENTALS NEEDED (Checkoff List Summary)

Fig. 4--Type of Technician

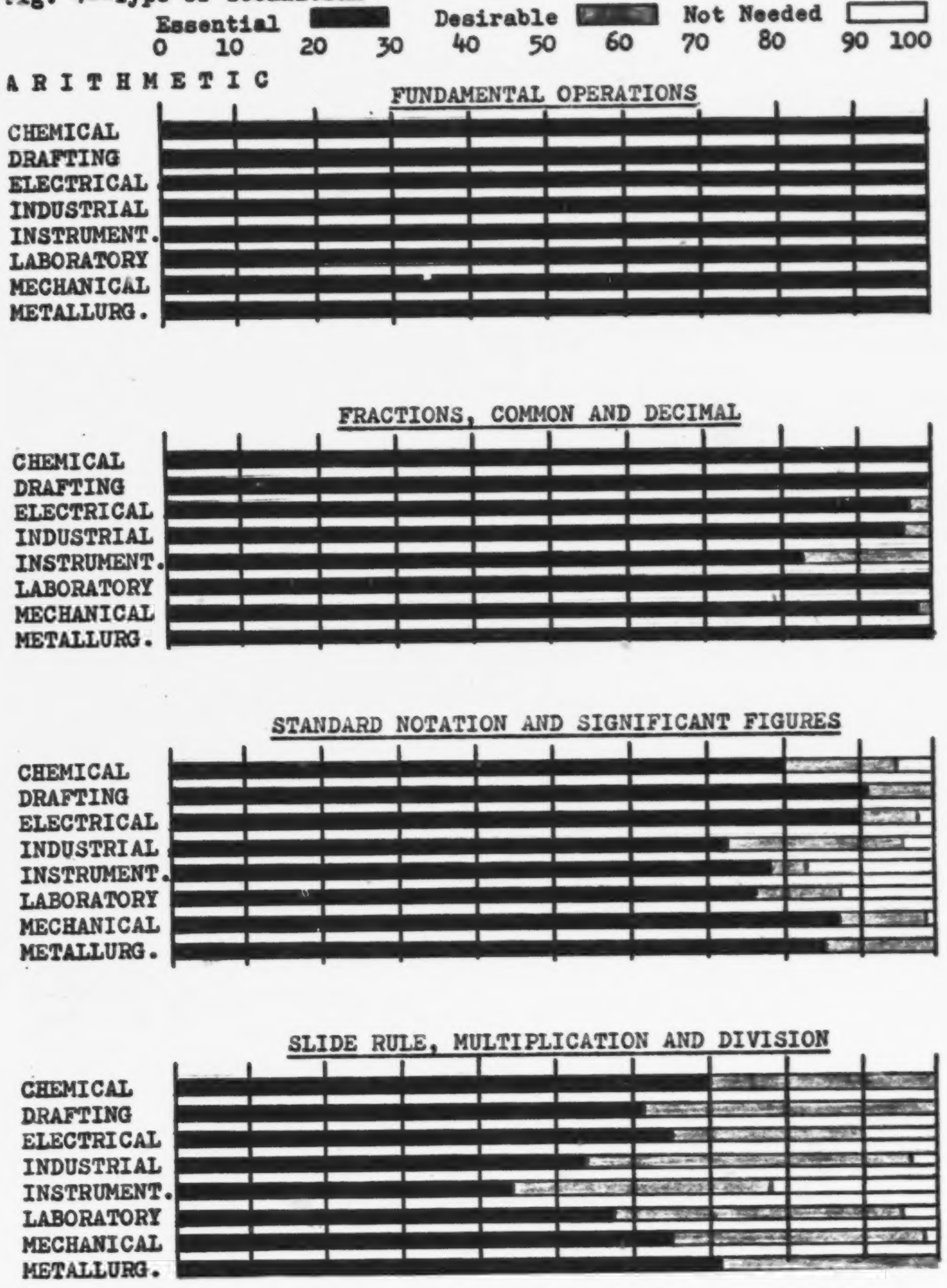


Fig. 4--Type of Technician continued

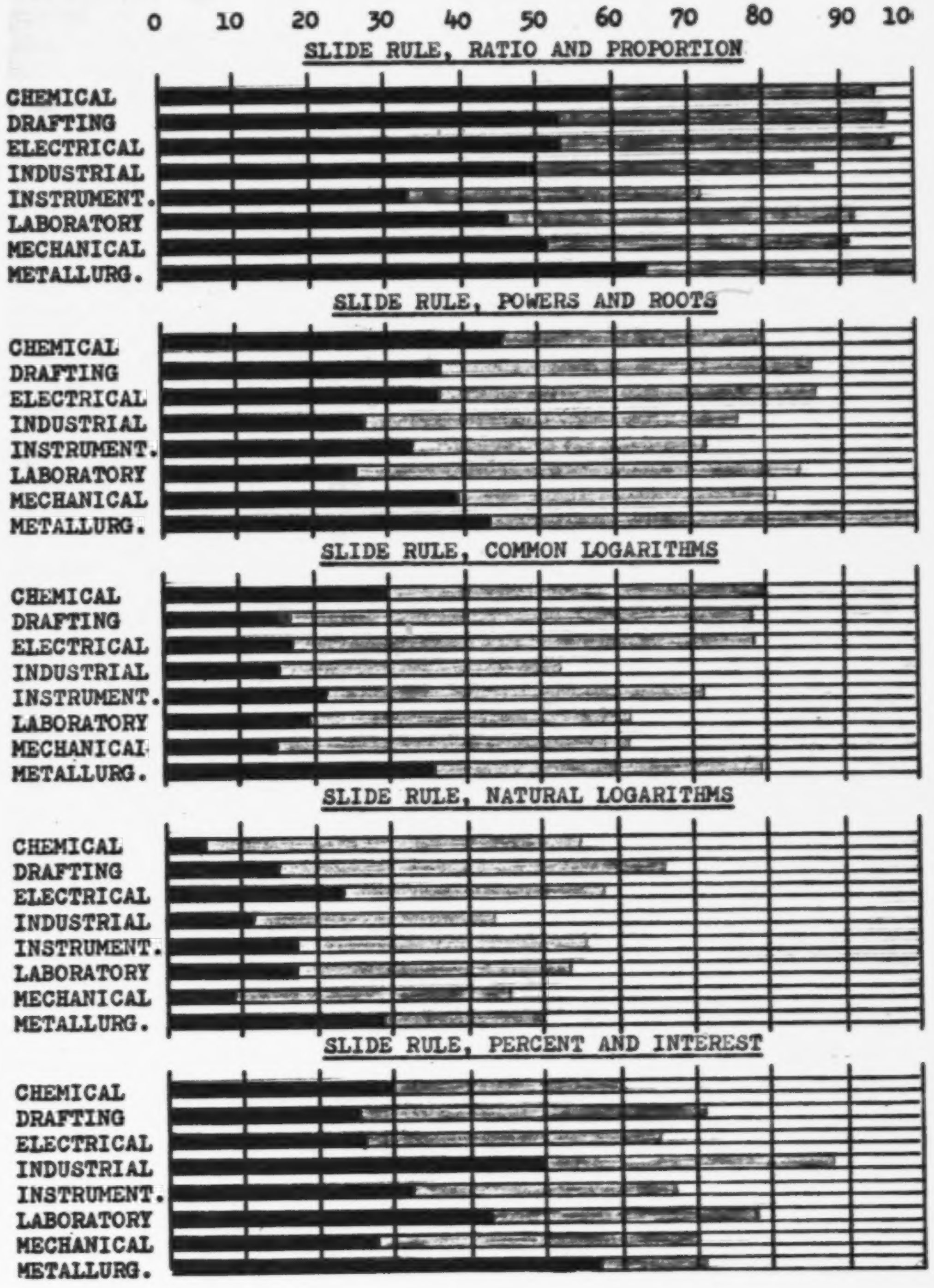


Fig. 4--Type of Technician Continued

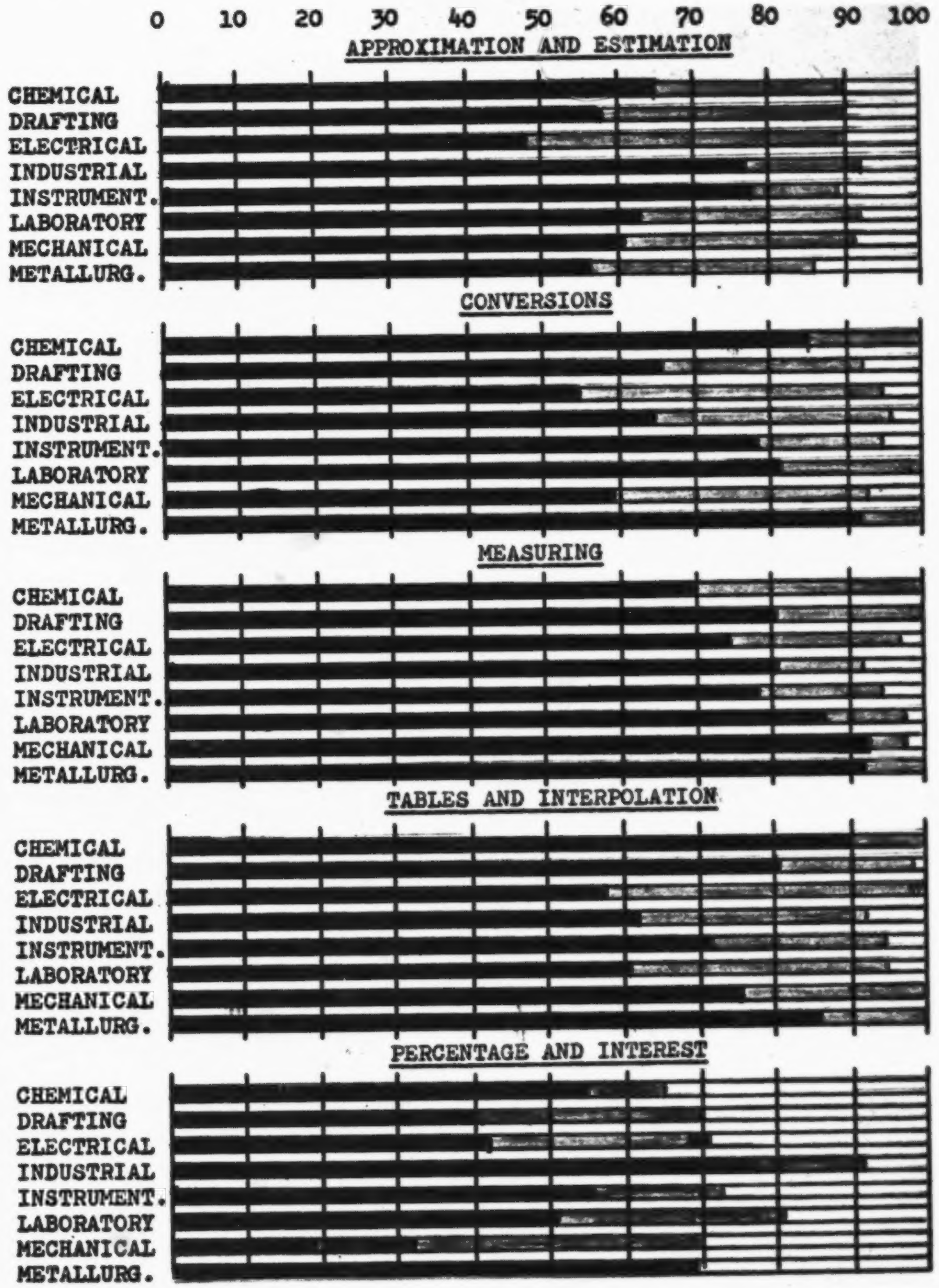


Fig. 4--Type of Technician continued

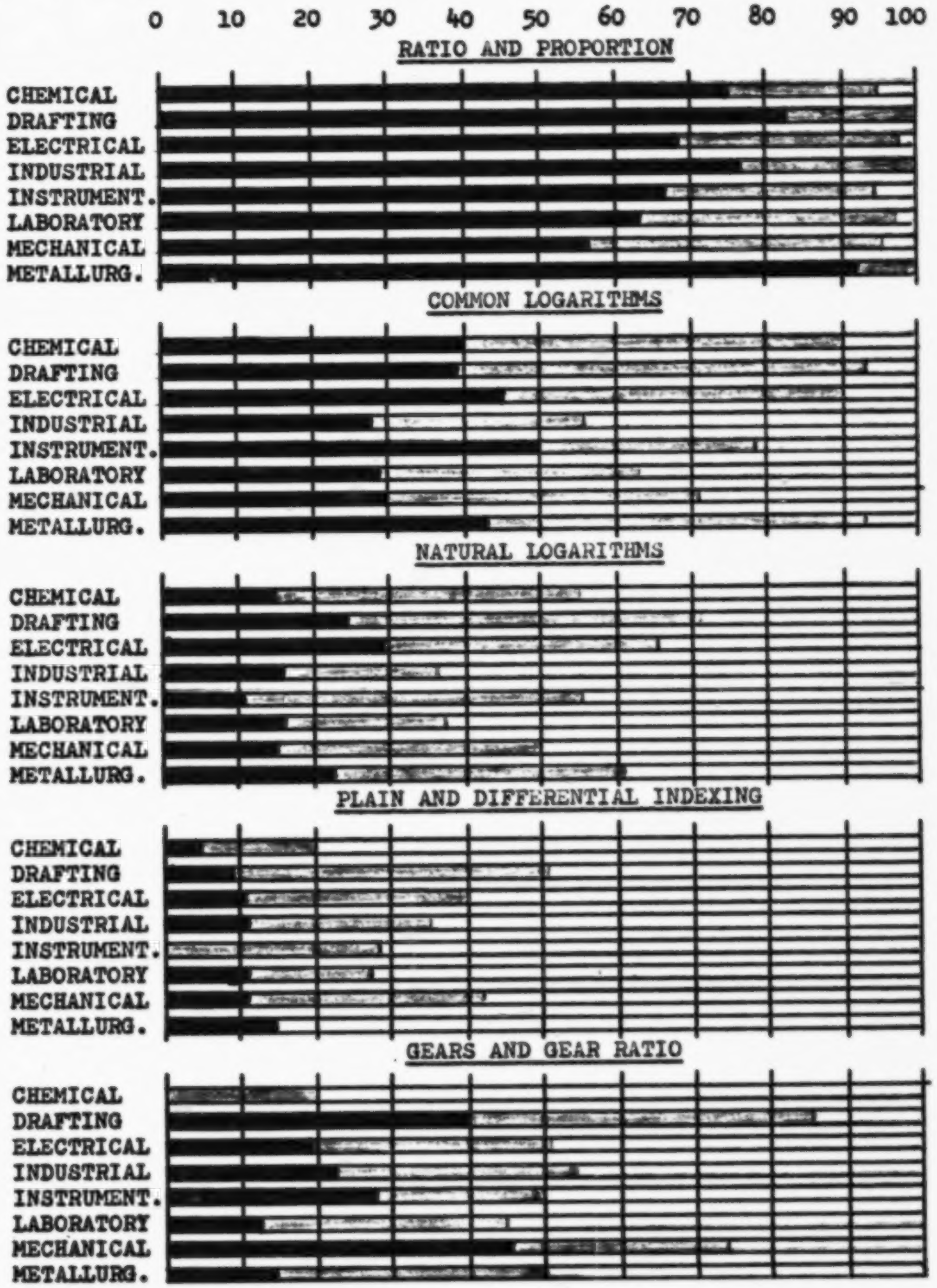


Fig. 4--Type of Technician continued

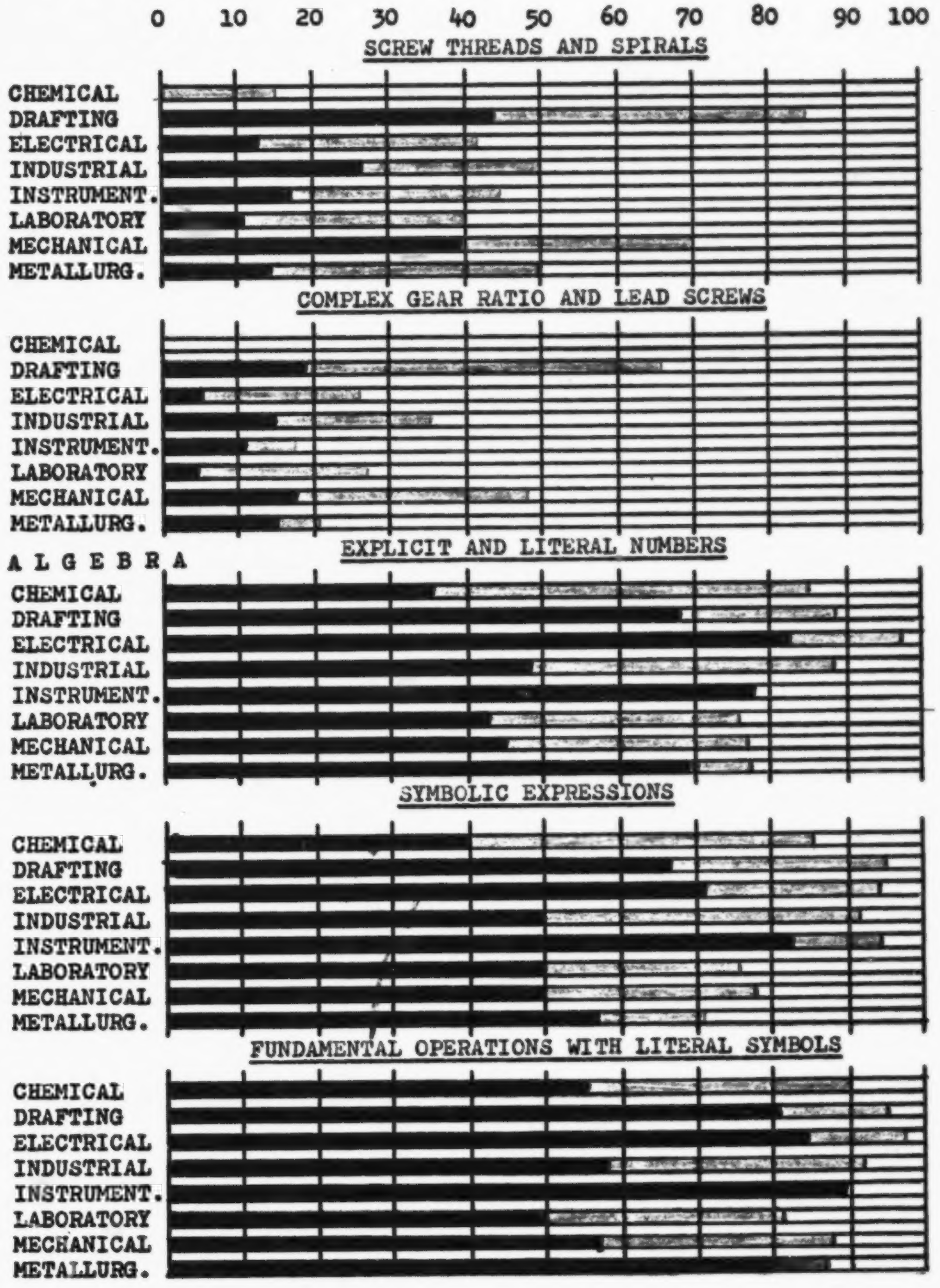


Fig. 4--Type of Technician continued

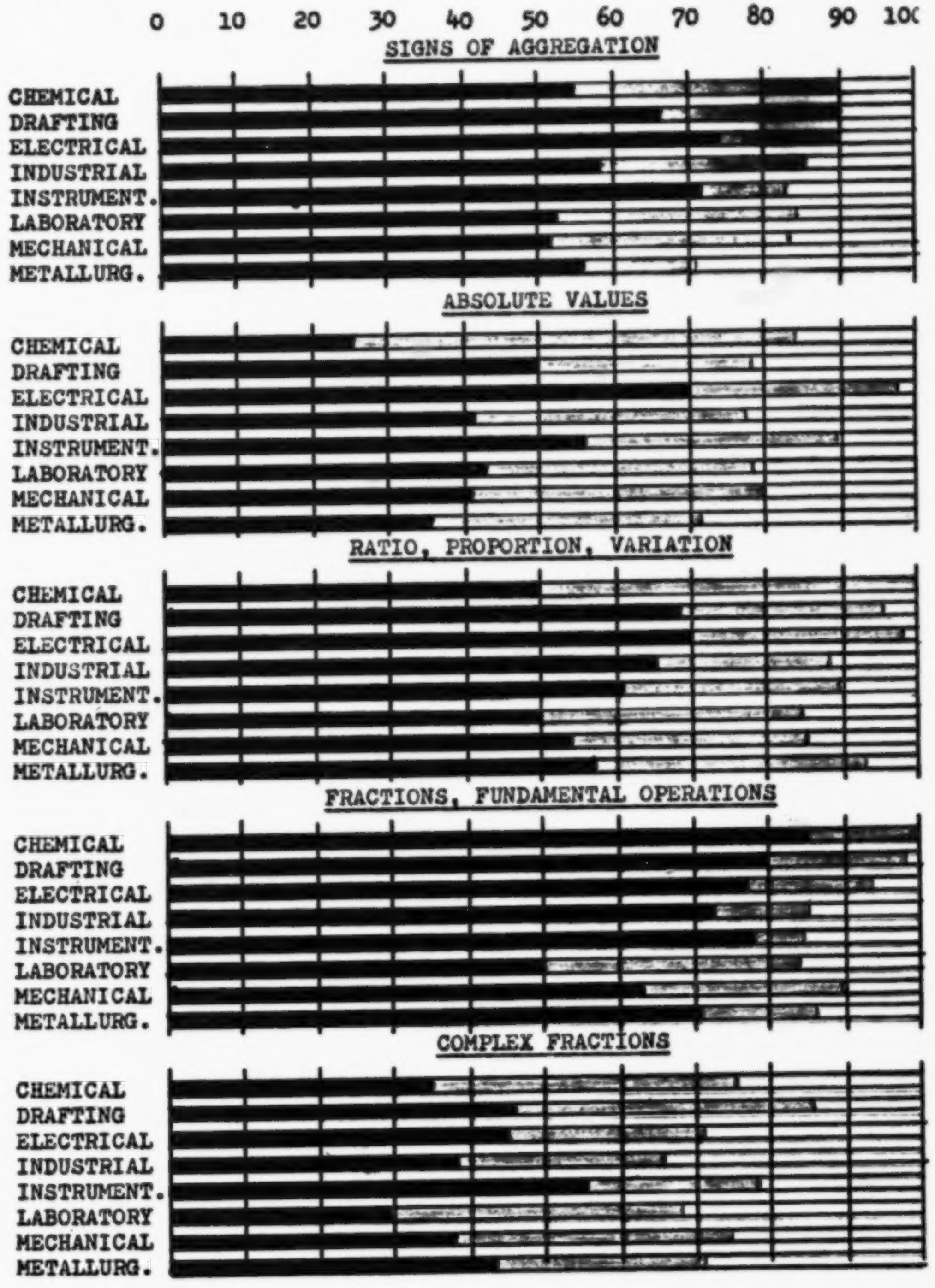


Fig. 4--Type of Technician continued

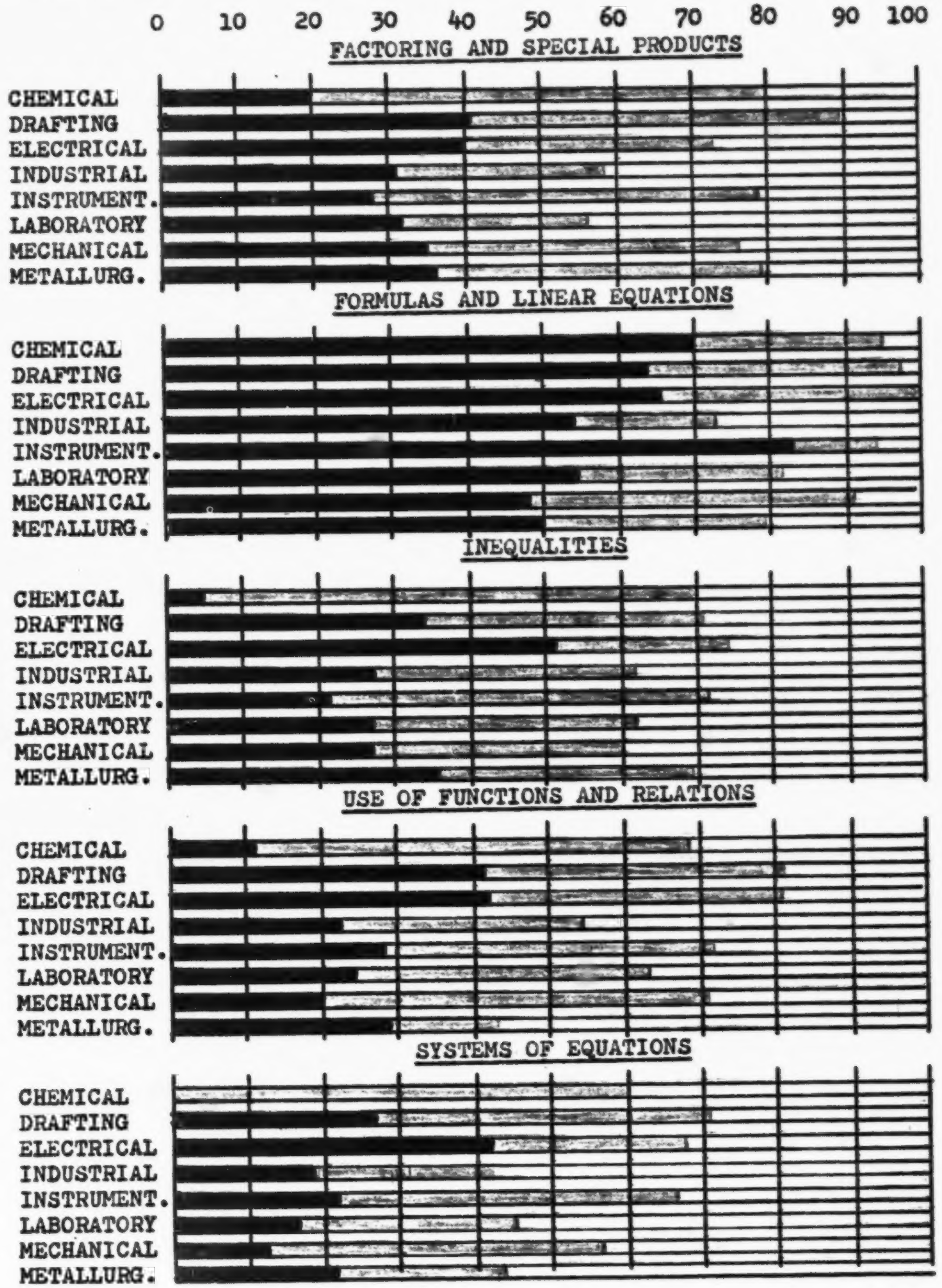


Fig. 4--Type of Technician continued

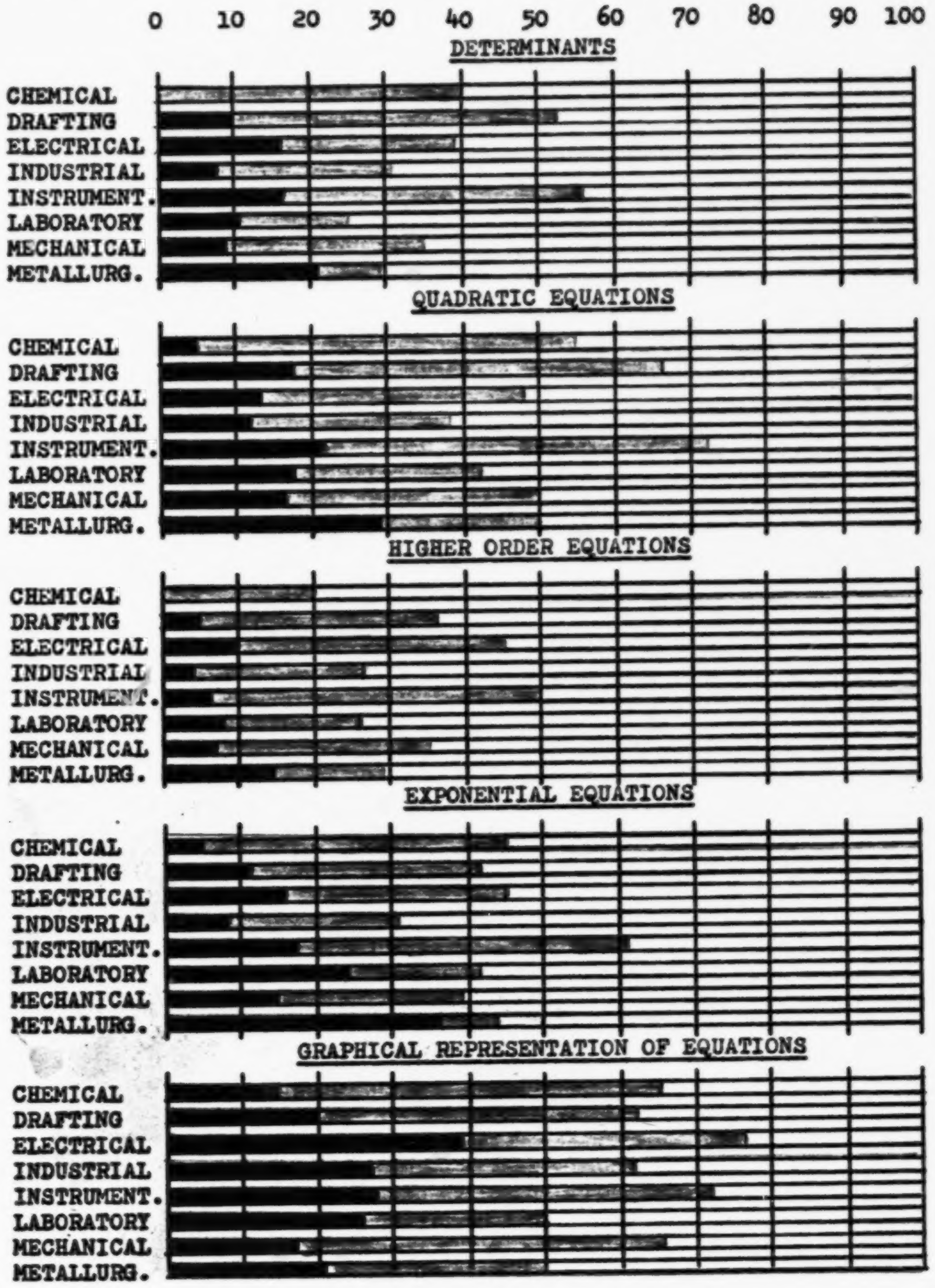
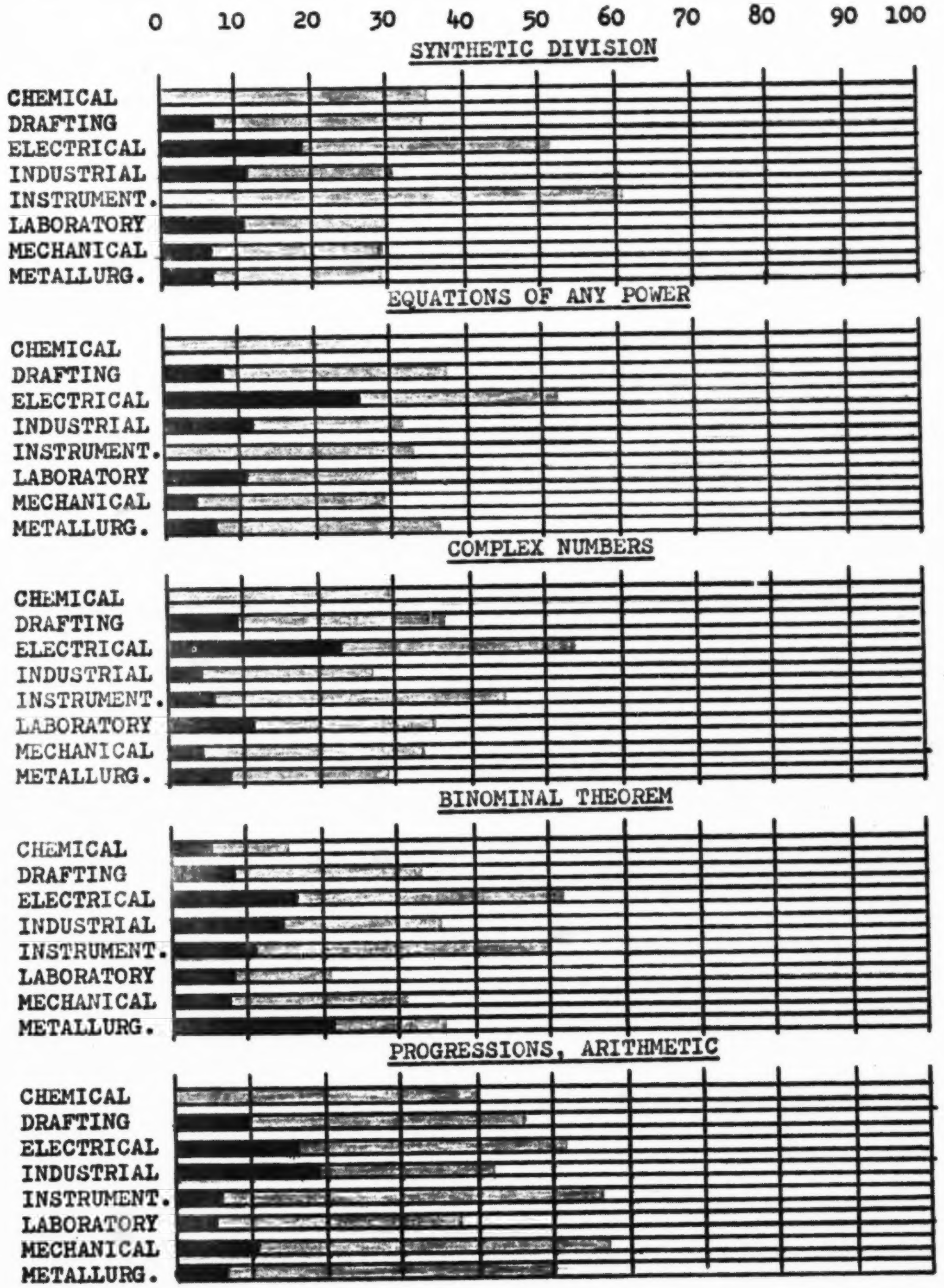


Fig. 4--Type of Technician continued



SYNTHETIC DIVISION

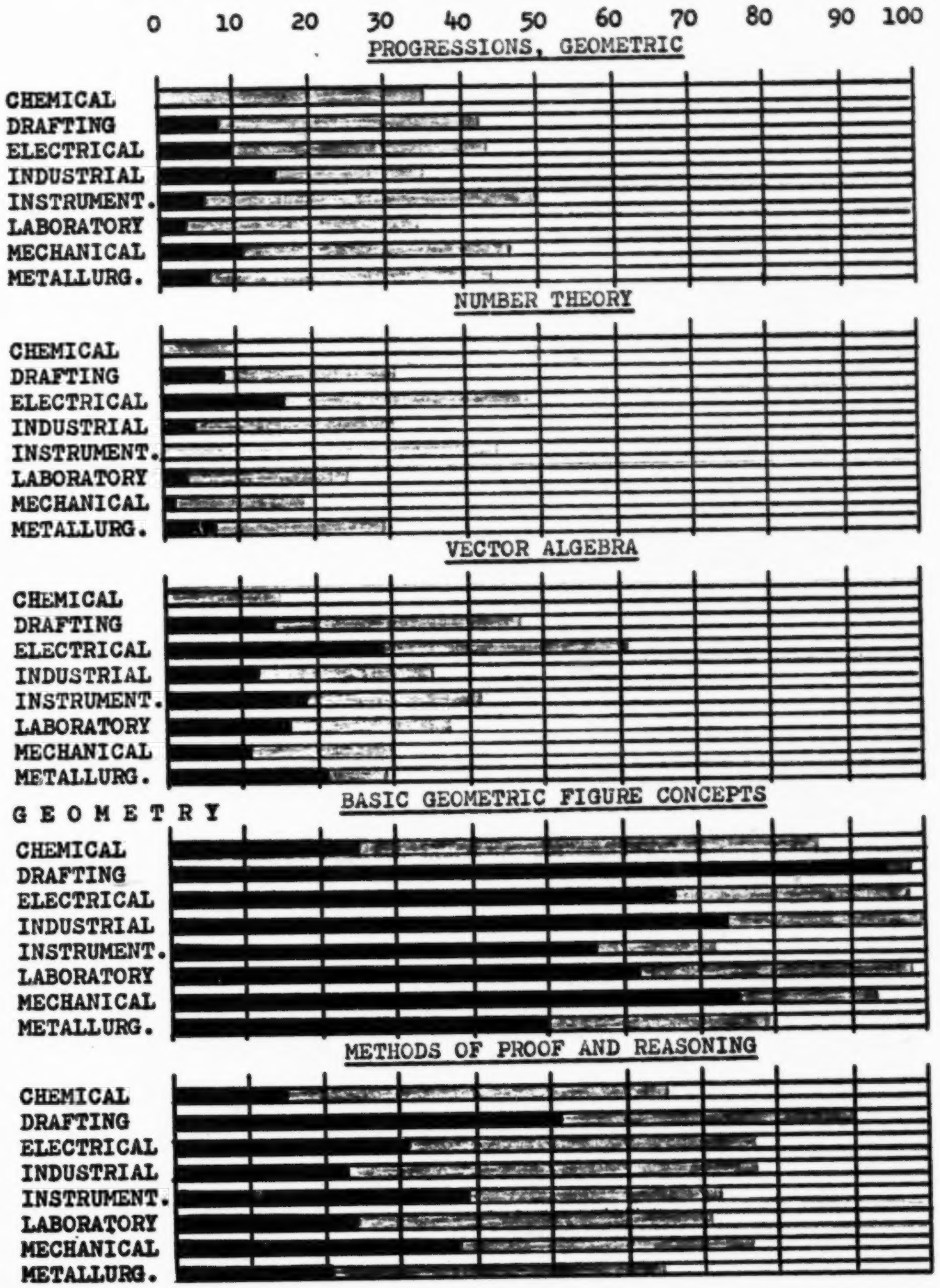
EQUATIONS OF ANY POWER

COMPLEX NUMBERS

BINOMINAL THEOREM

PROGRESSIONS, ARITHMETIC

Fig. 4--Type of Technician continued



PROGRESSIONS, GEOMETRIC

NUMBER THEORY

VECTOR ALGEBRA

GEOMETRY

BASIC GEOMETRIC FIGURE CONCEPTS

METHODS OF PROOF AND REASONING

Fig. 4--Type of Technician *continued*

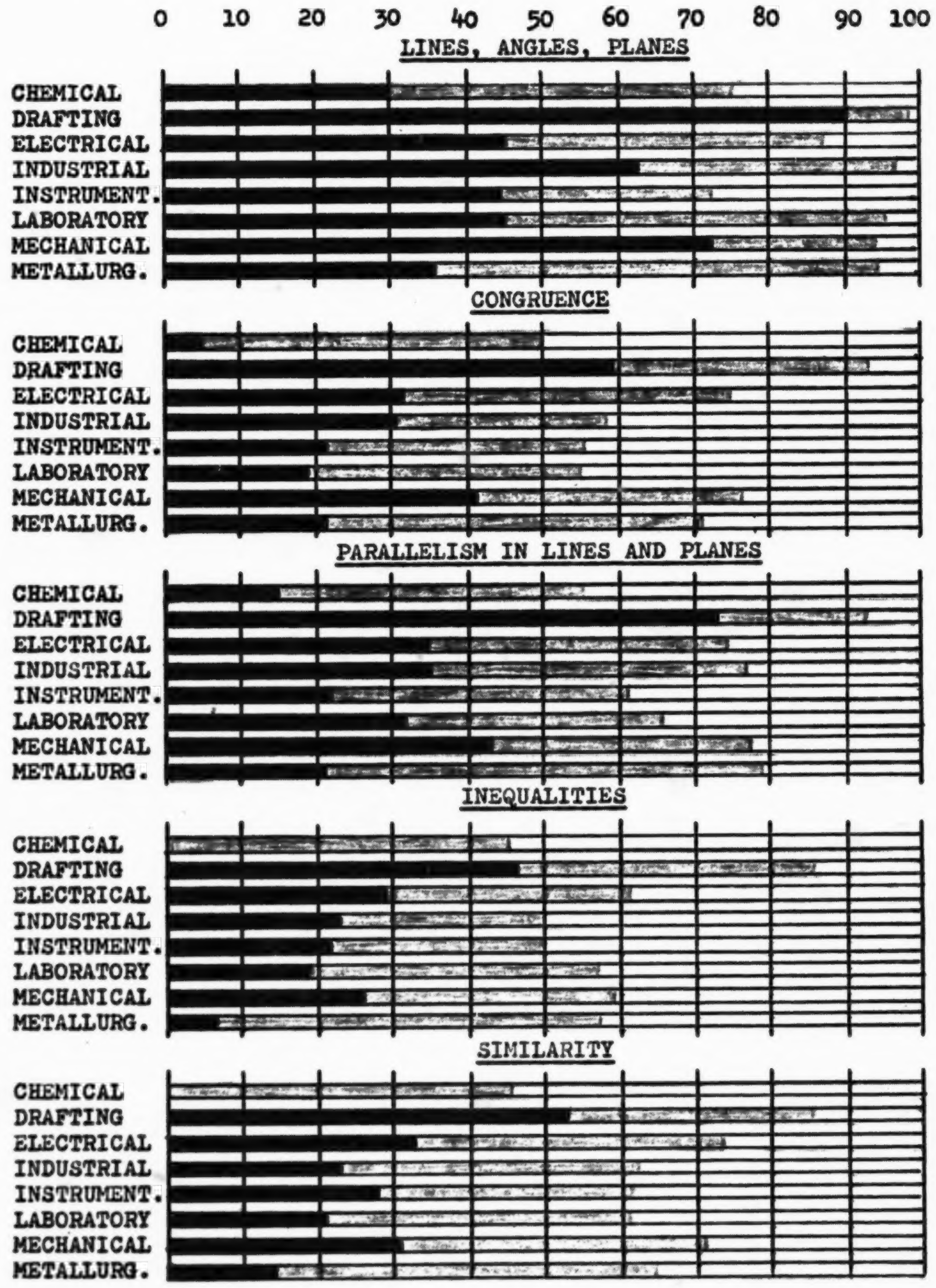


Fig. 4--Type of Technician *continued*

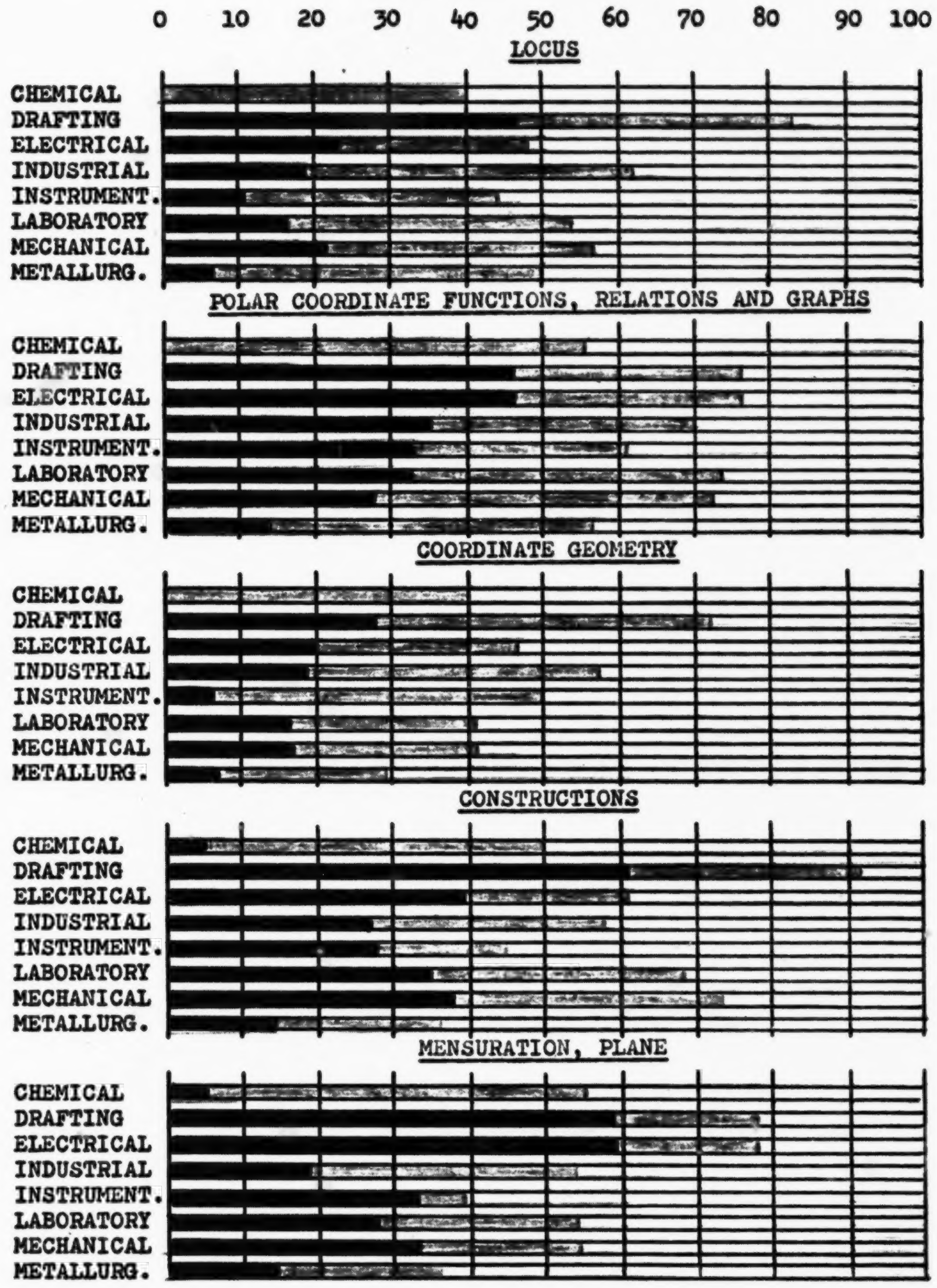
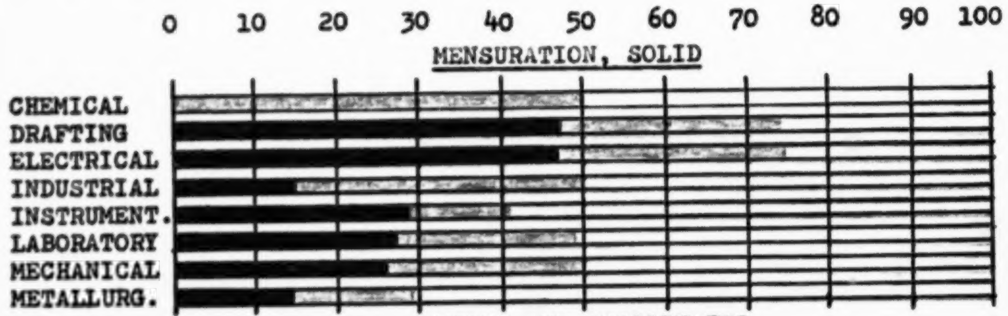
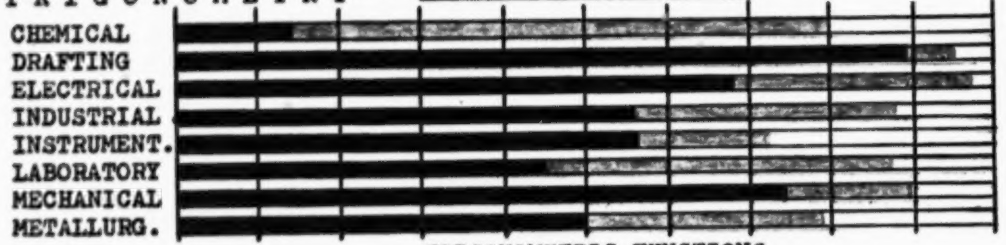


Fig. 4--Type of Technician continued

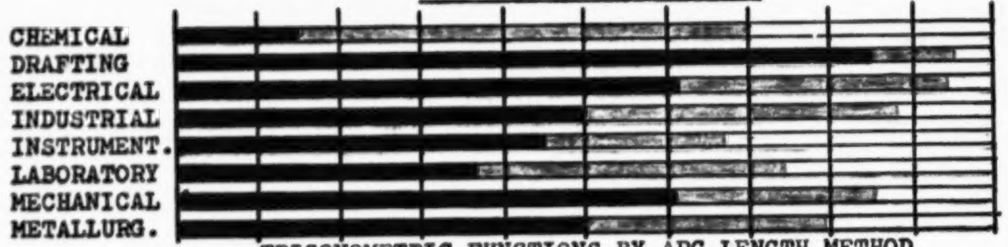

MENSURATION, SOLID

T R I G O N O M E T R Y

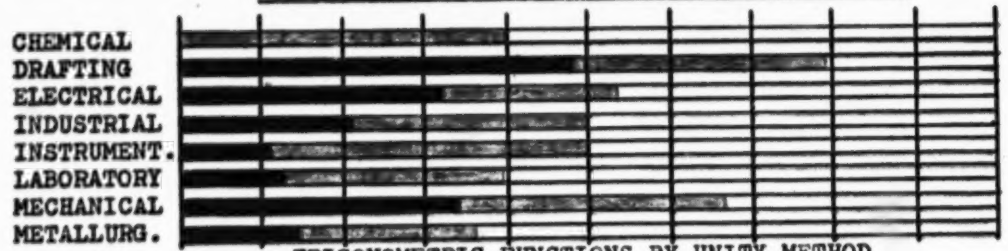
ANGLES AND COORDINATES



TRIGONOMETRIC FUNCTIONS



TRIGONOMETRIC FUNCTIONS BY ARC LENGTH METHOD



TRIGONOMETRIC FUNCTIONS BY UNITY METHOD

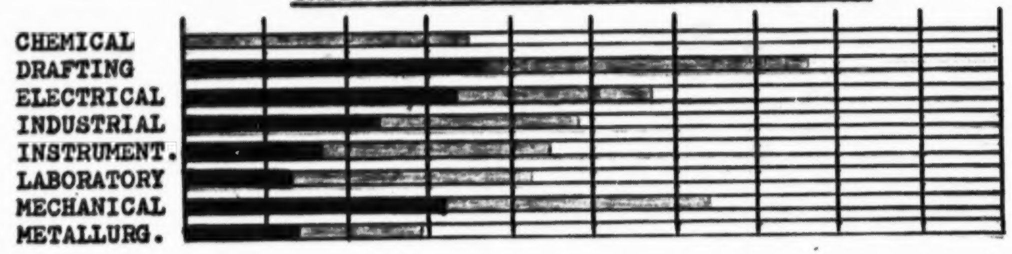
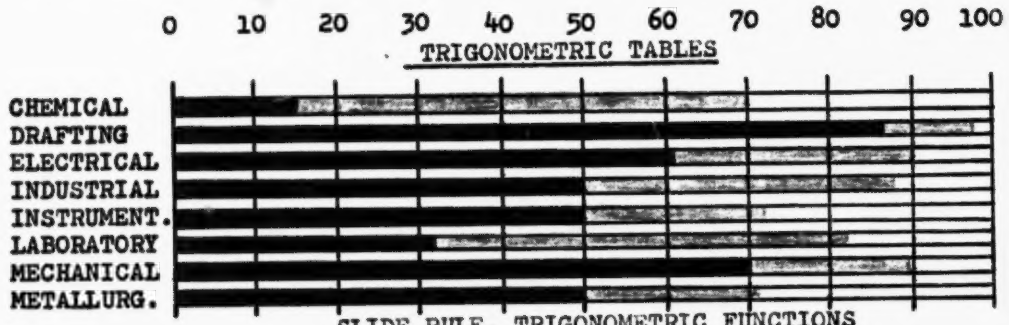
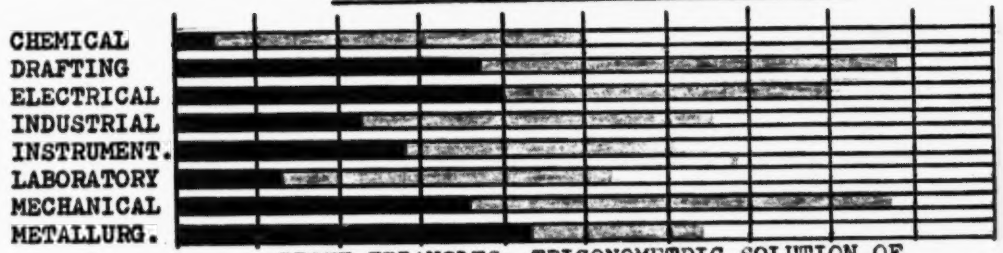


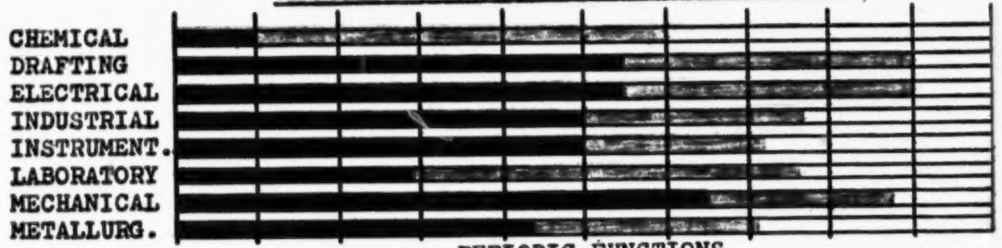
Fig. 4--Type of Technician continued


TRIGONOMETRIC TABLES

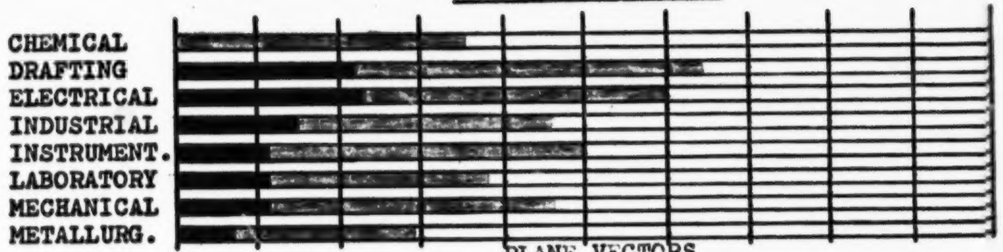
SLIDE RULE, TRIGONOMETRIC FUNCTIONS



RIGHT TRIANGLES, TRIGONOMETRIC SOLUTION OF



PERIODIC FUNCTIONS



PLANE VECTORS

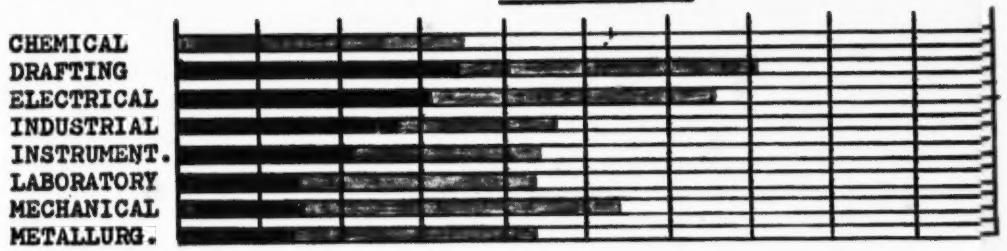


Fig. 4--Type of Technician Continued

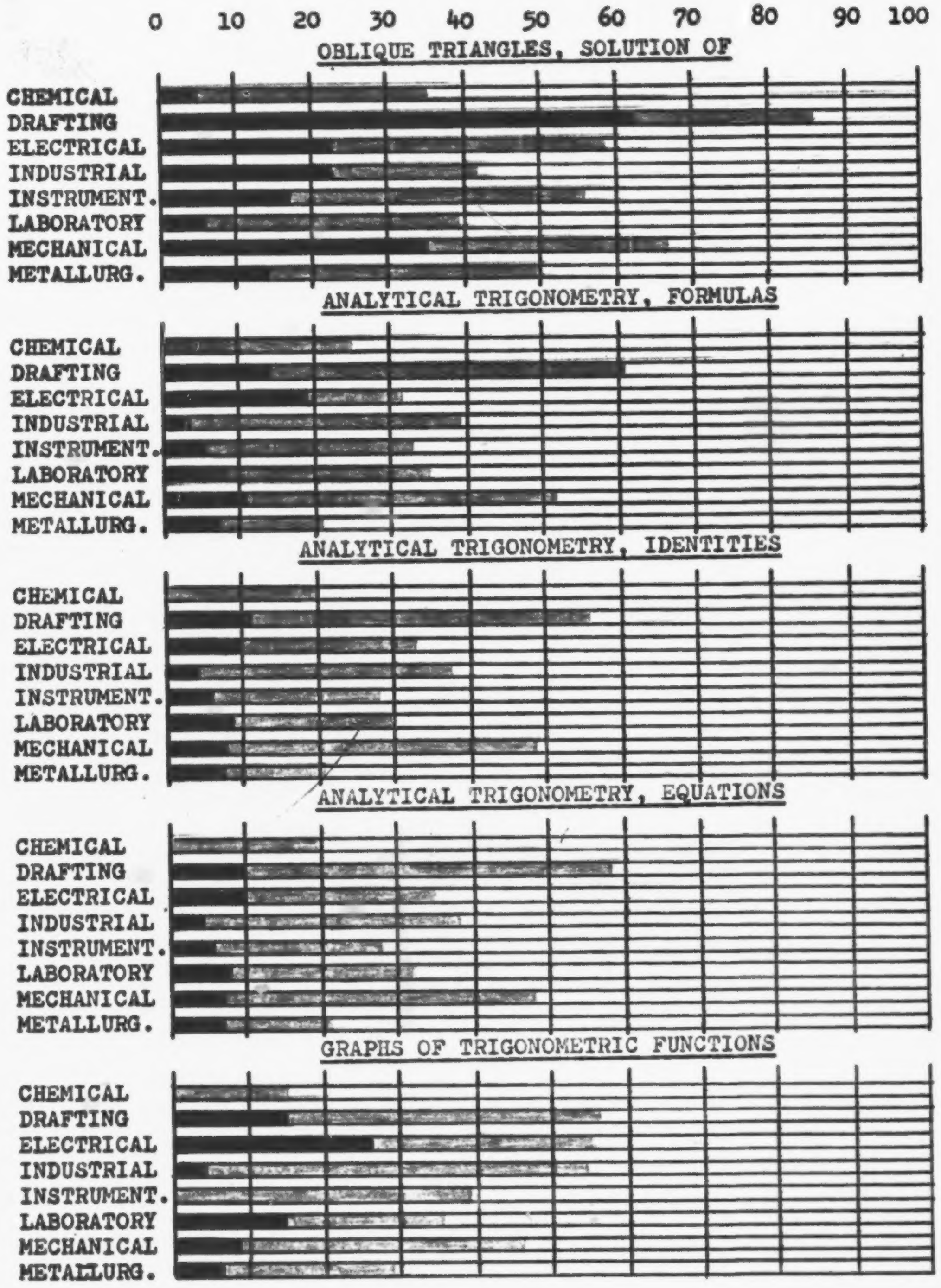


Fig. 4--Type of Technician continued

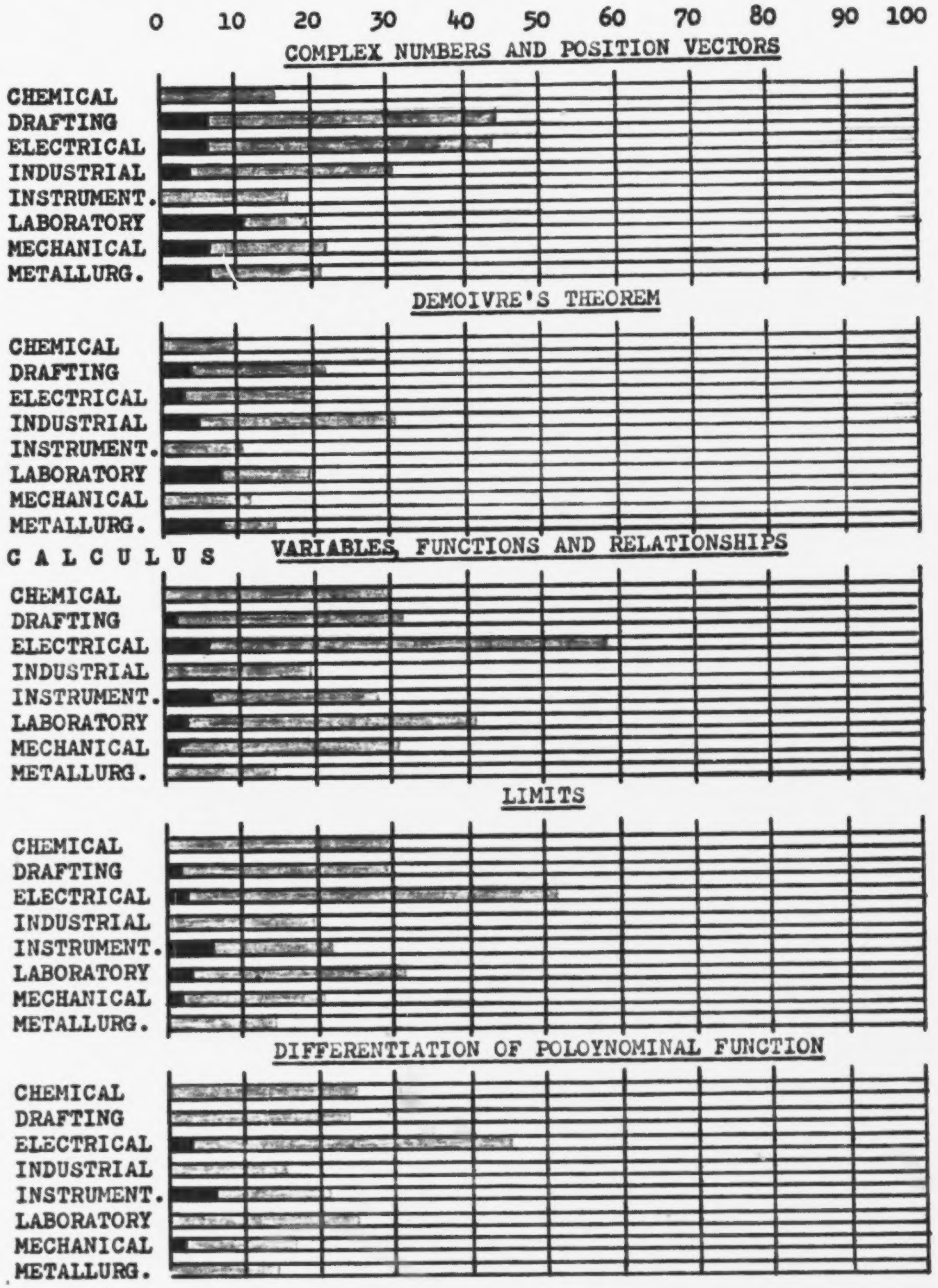
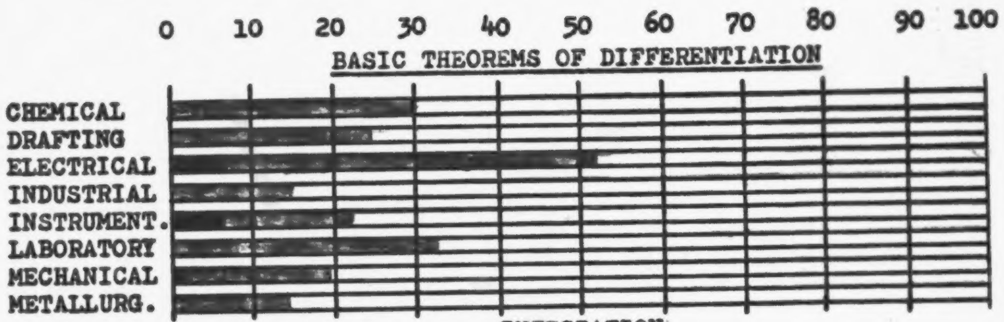
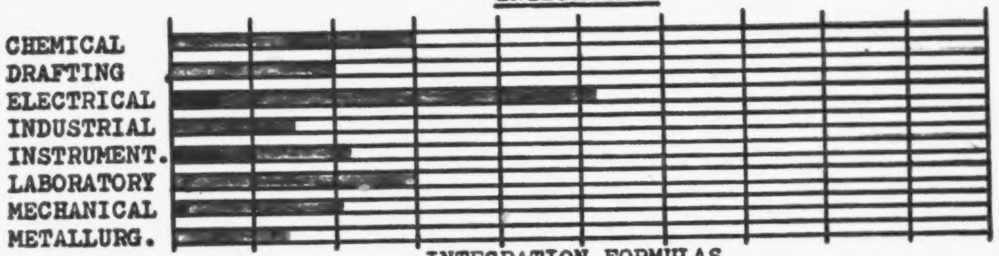


Fig. 4--Type of Technician continued

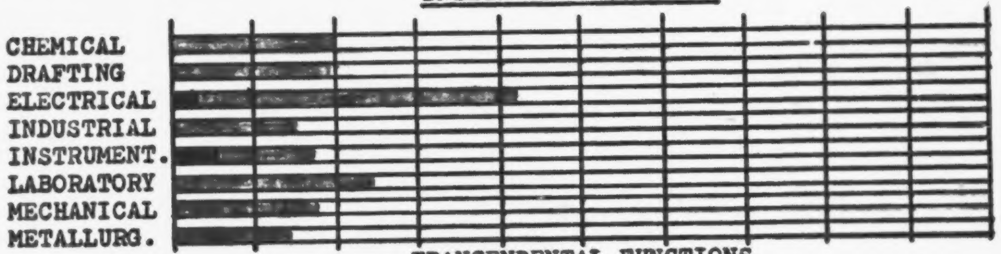
BASIC THEOREMS OF DIFFERENTIATION



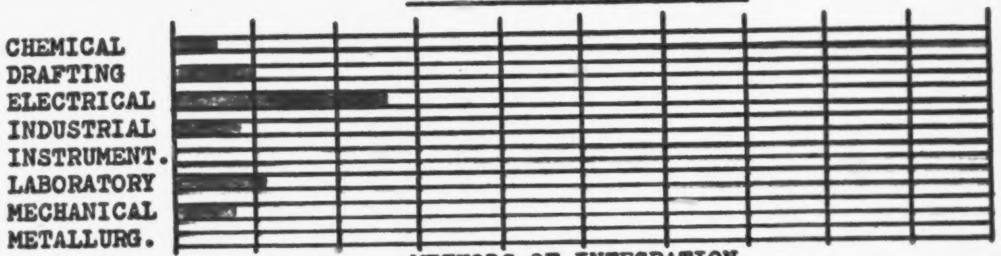
INTEGRATION



INTEGRATION FORMULAS



TRANCENDENTAL FUNCTIONS



METHODS OF INTEGRATION

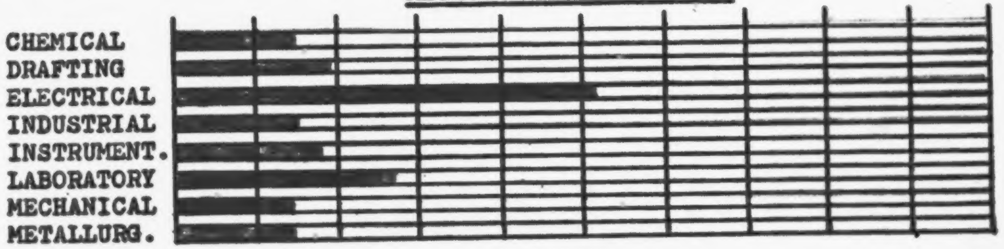
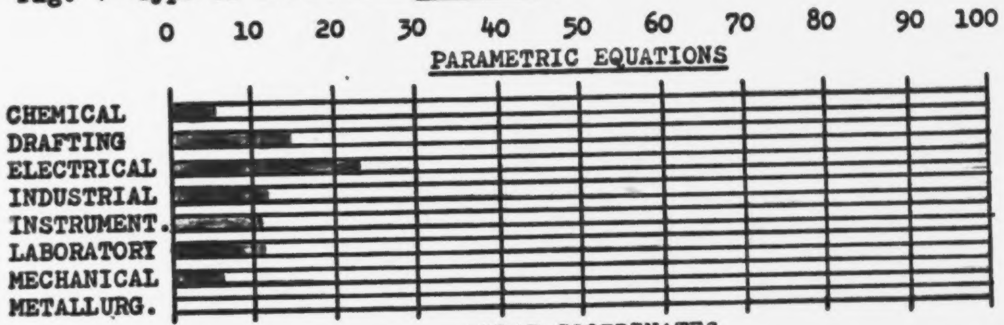
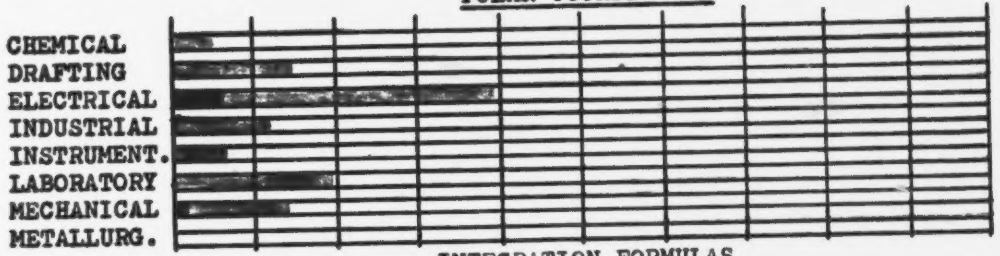


Fig. 4--Type of Technician continued

PARAMETRIC EQUATIONS



POLAR COORDINATES



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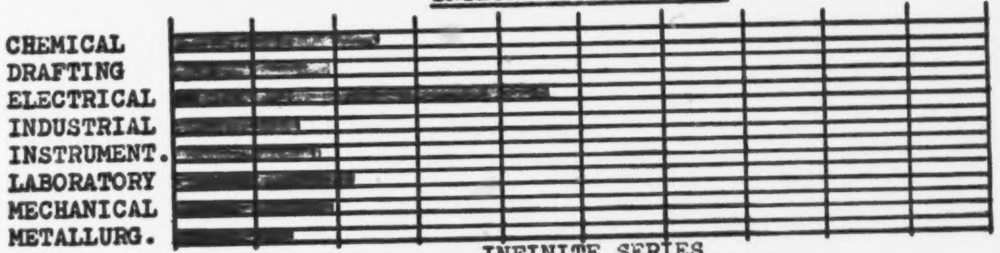
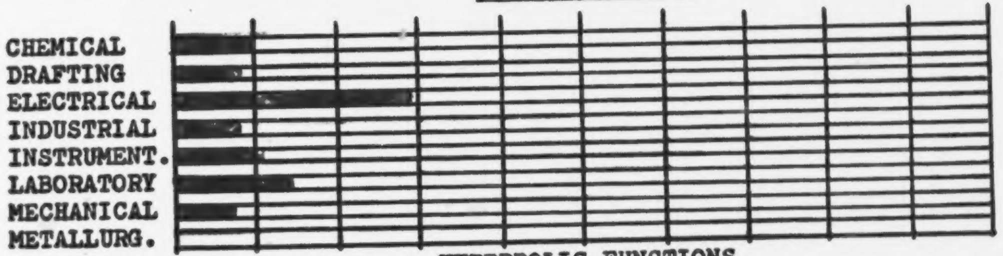


INFINITE SERIES



HYPERBOLIC FUNCTIONS

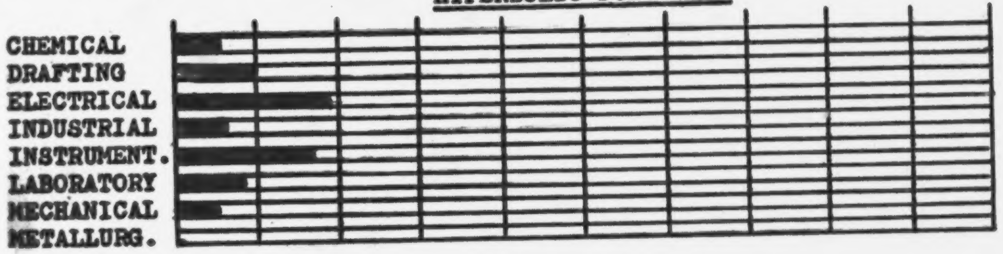
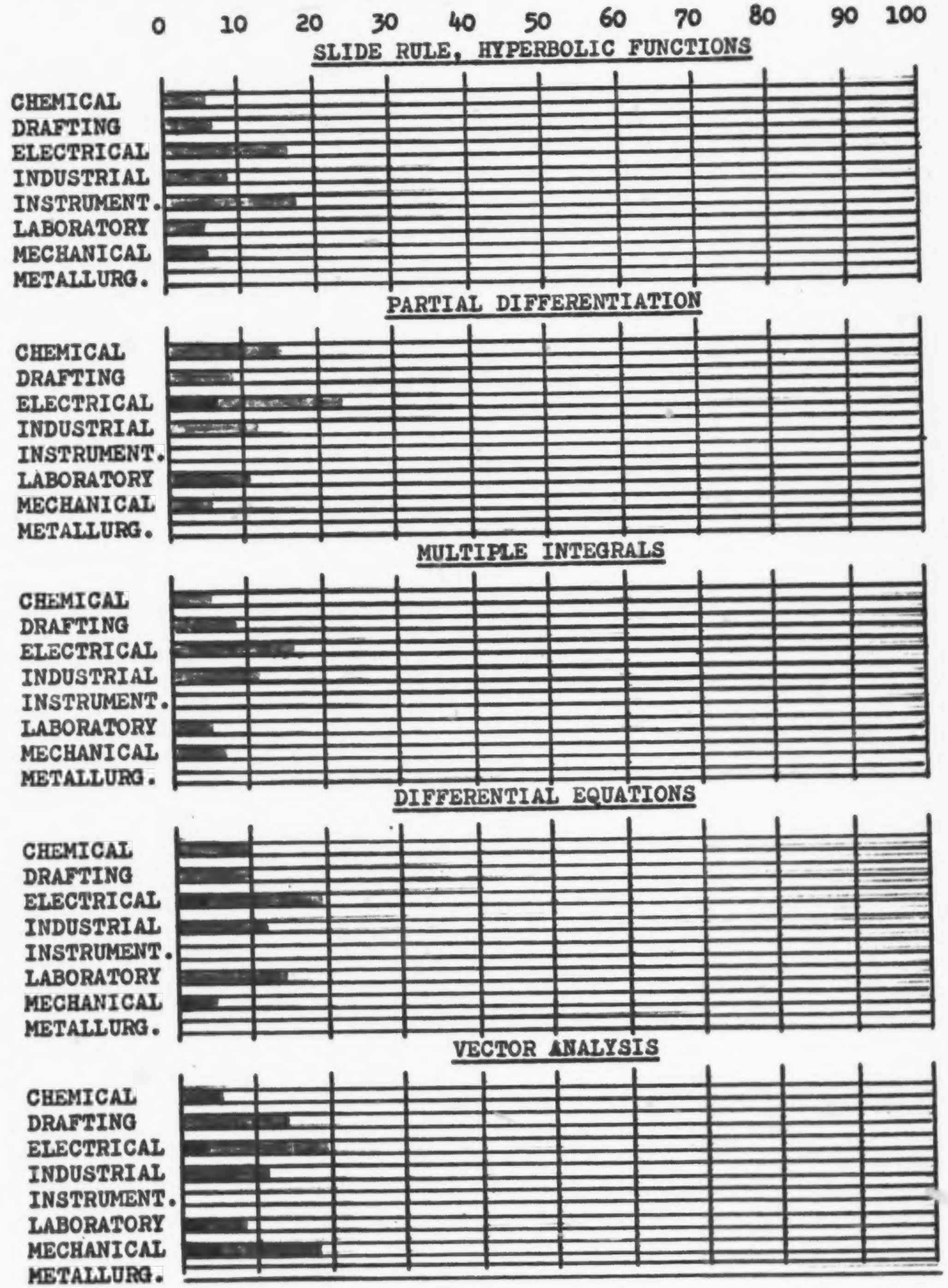


Fig. 4--Type of Technician continued



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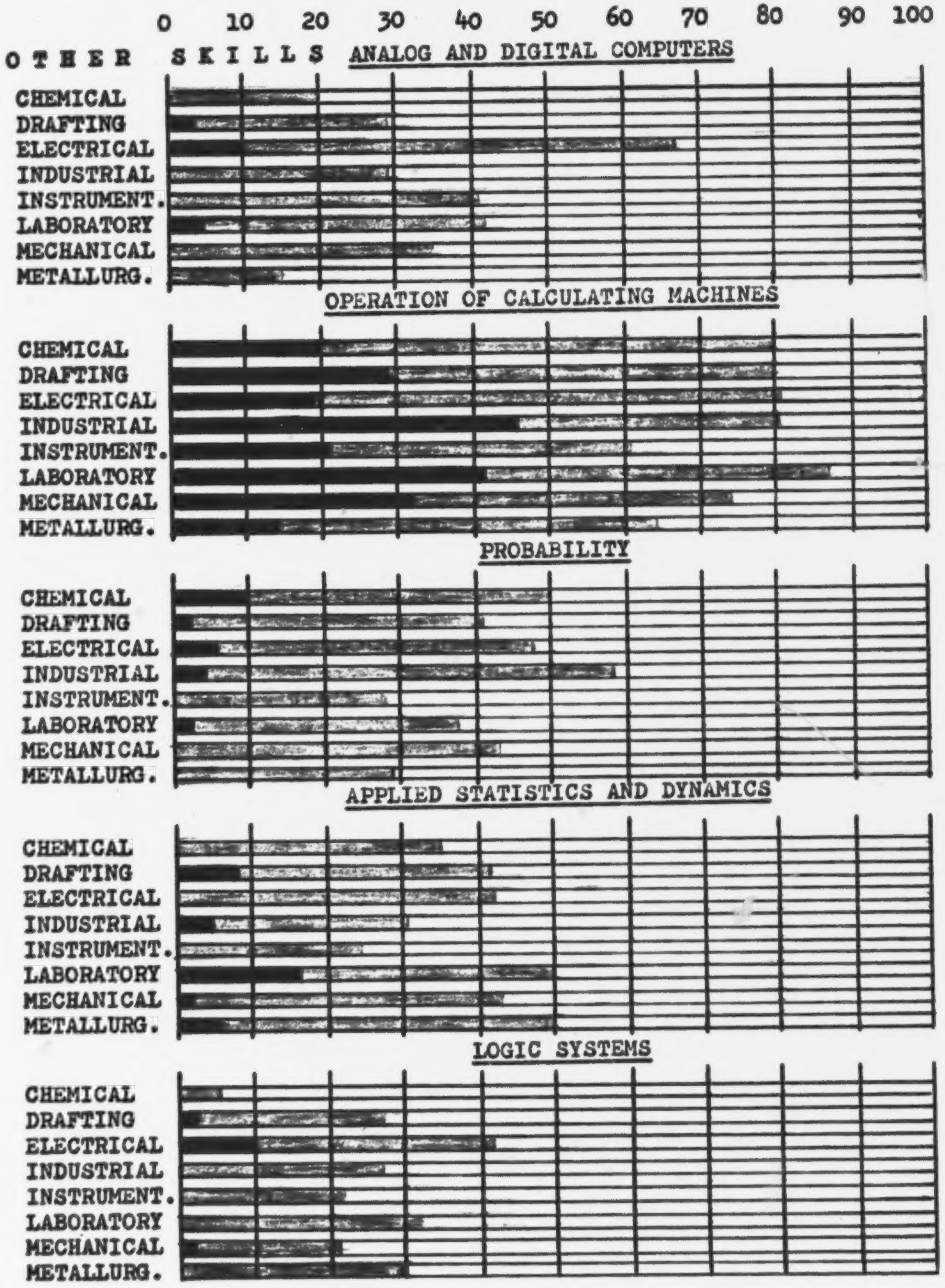


MATHEMATICAL FUNDAMENTALS NEEDED (Checkoff List Summary)

Fig. 4--Type of Technician continued

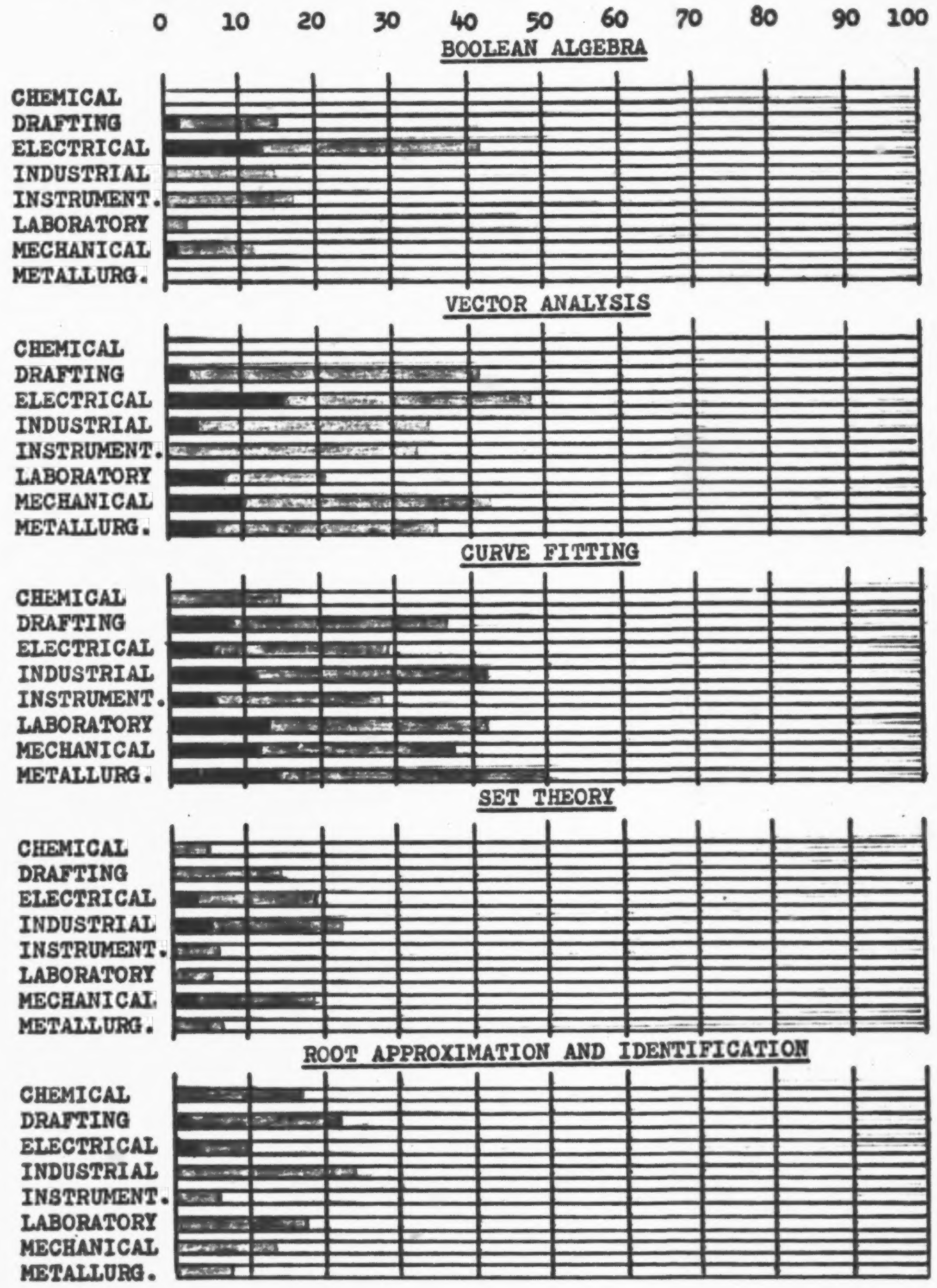
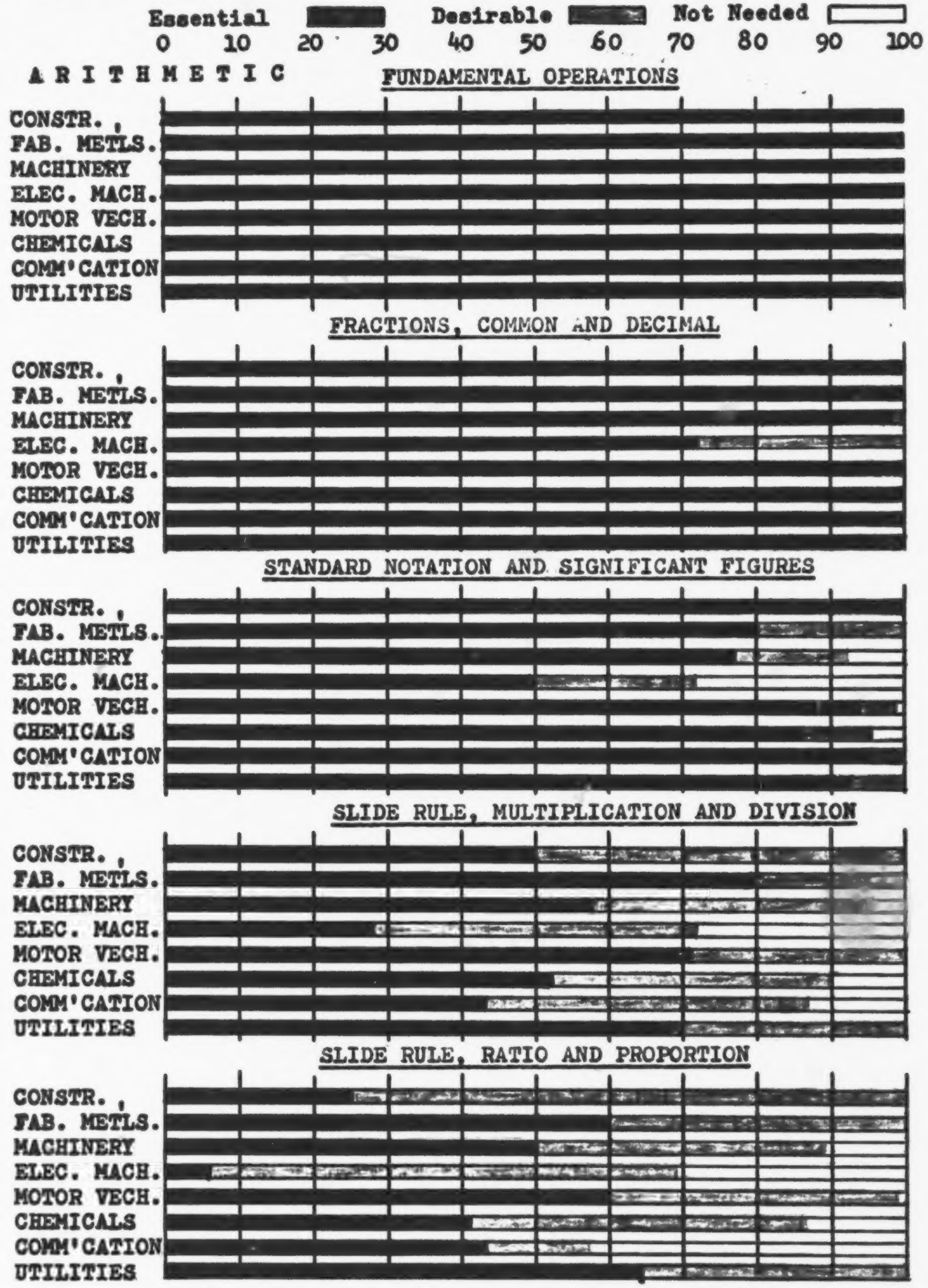


Fig. 5--Type of Industry



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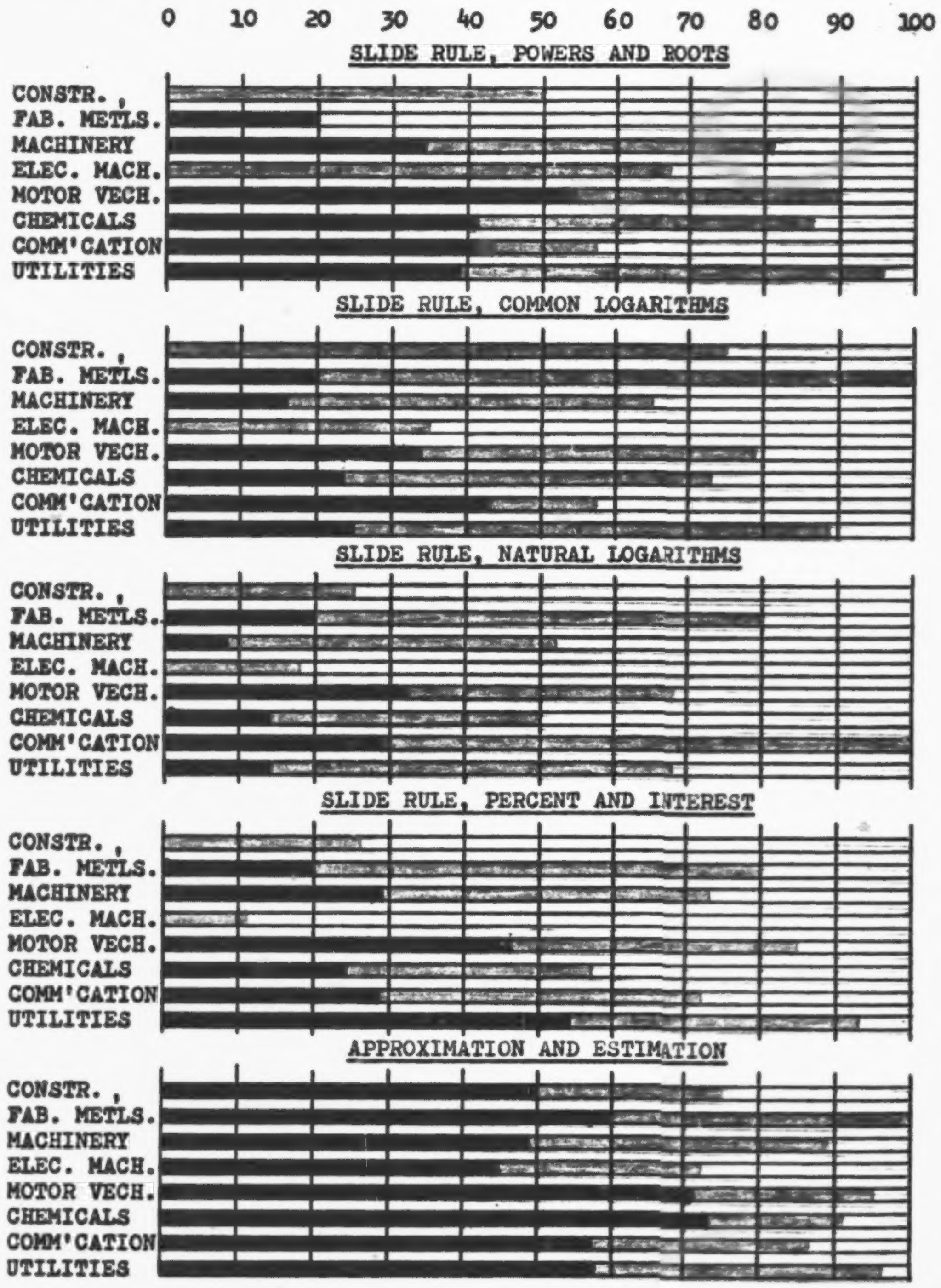

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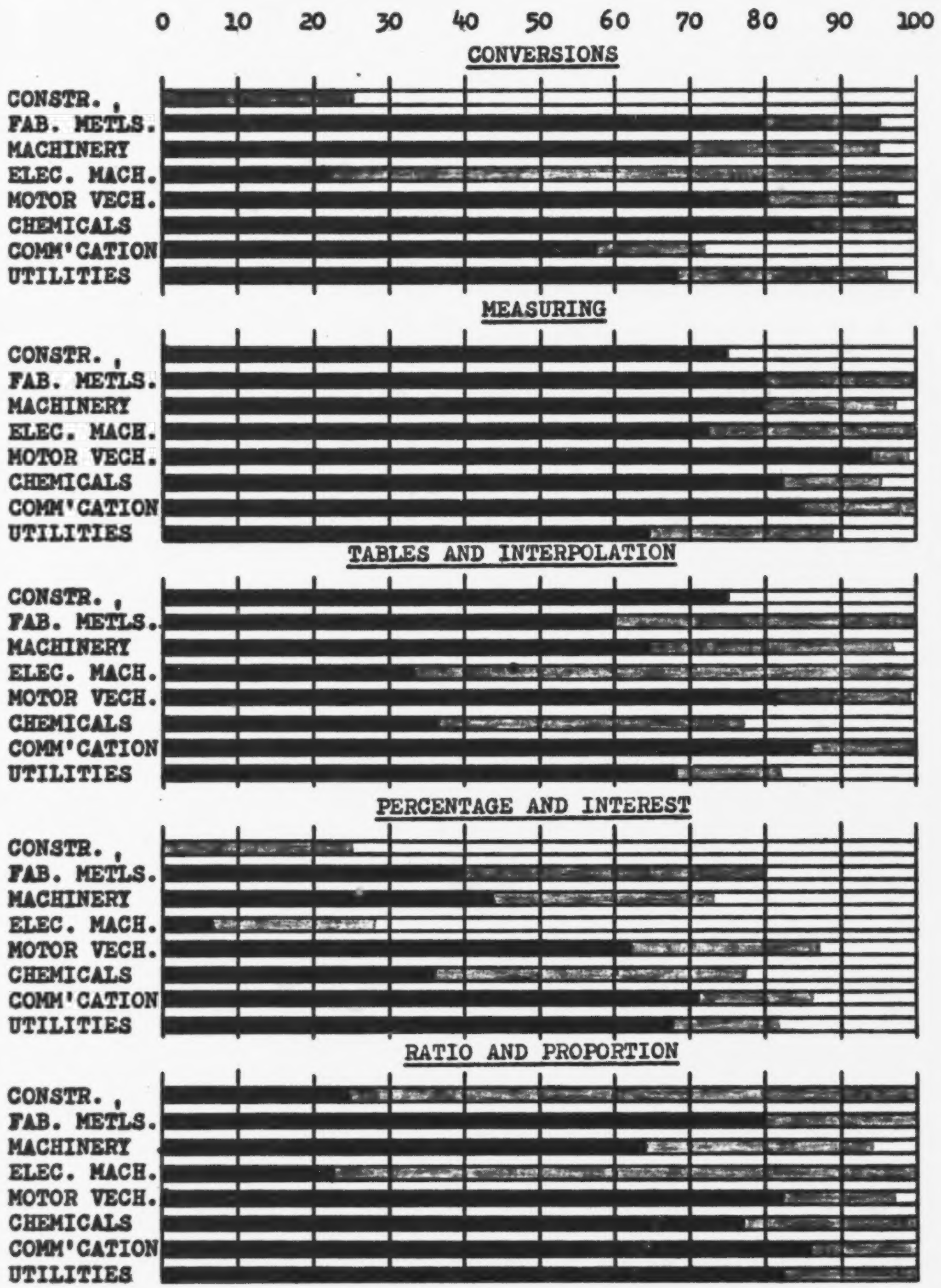

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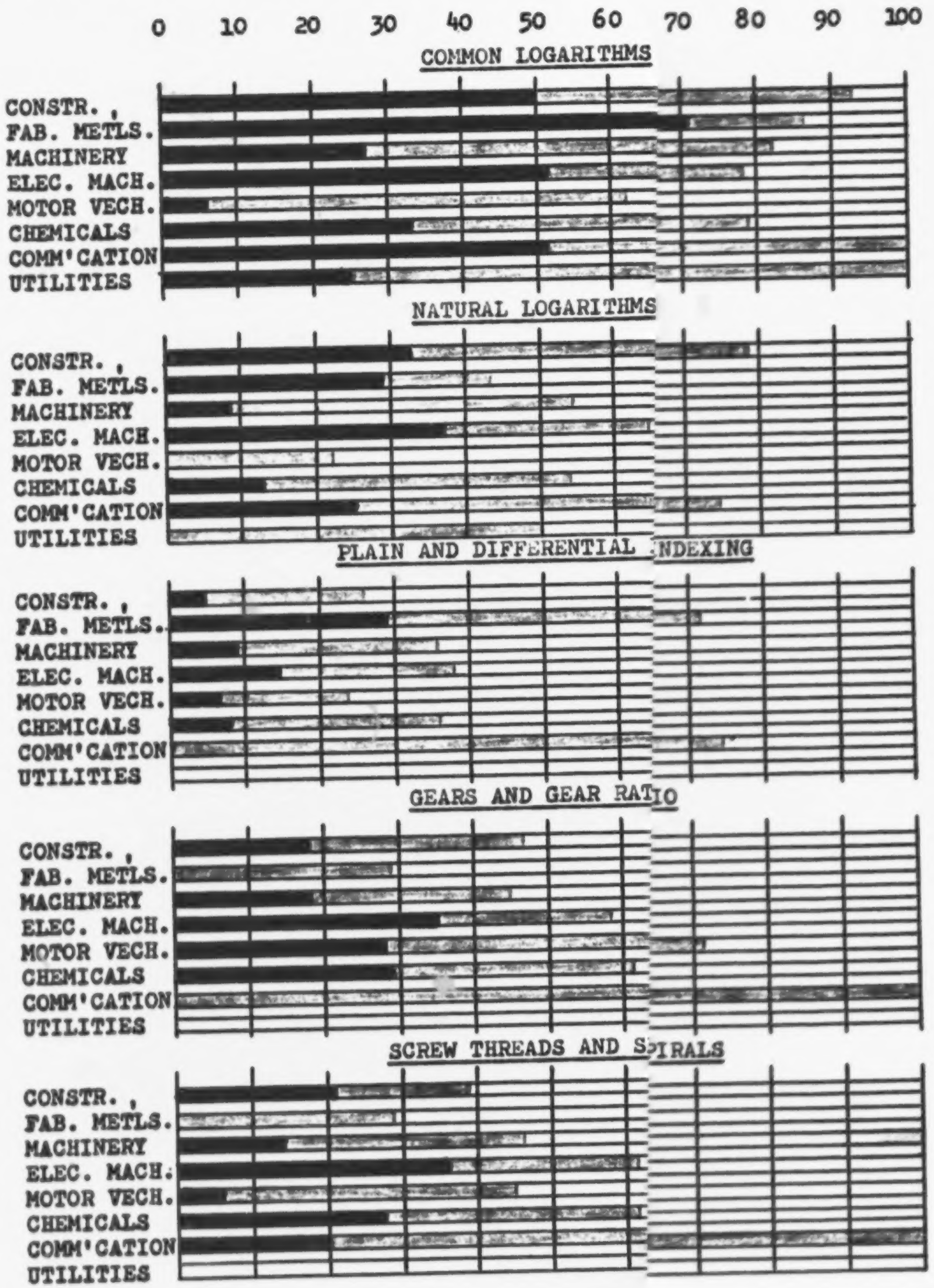

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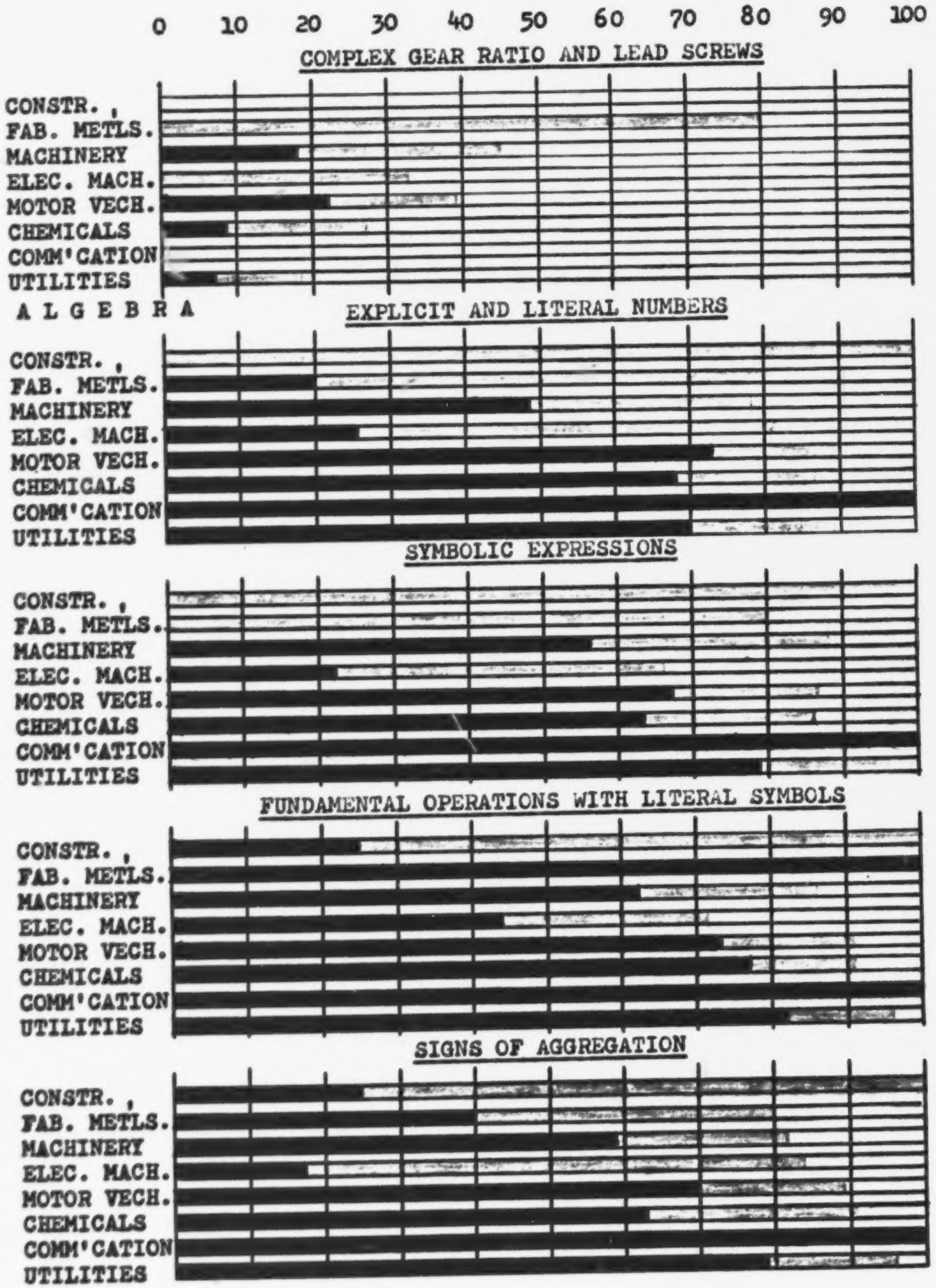

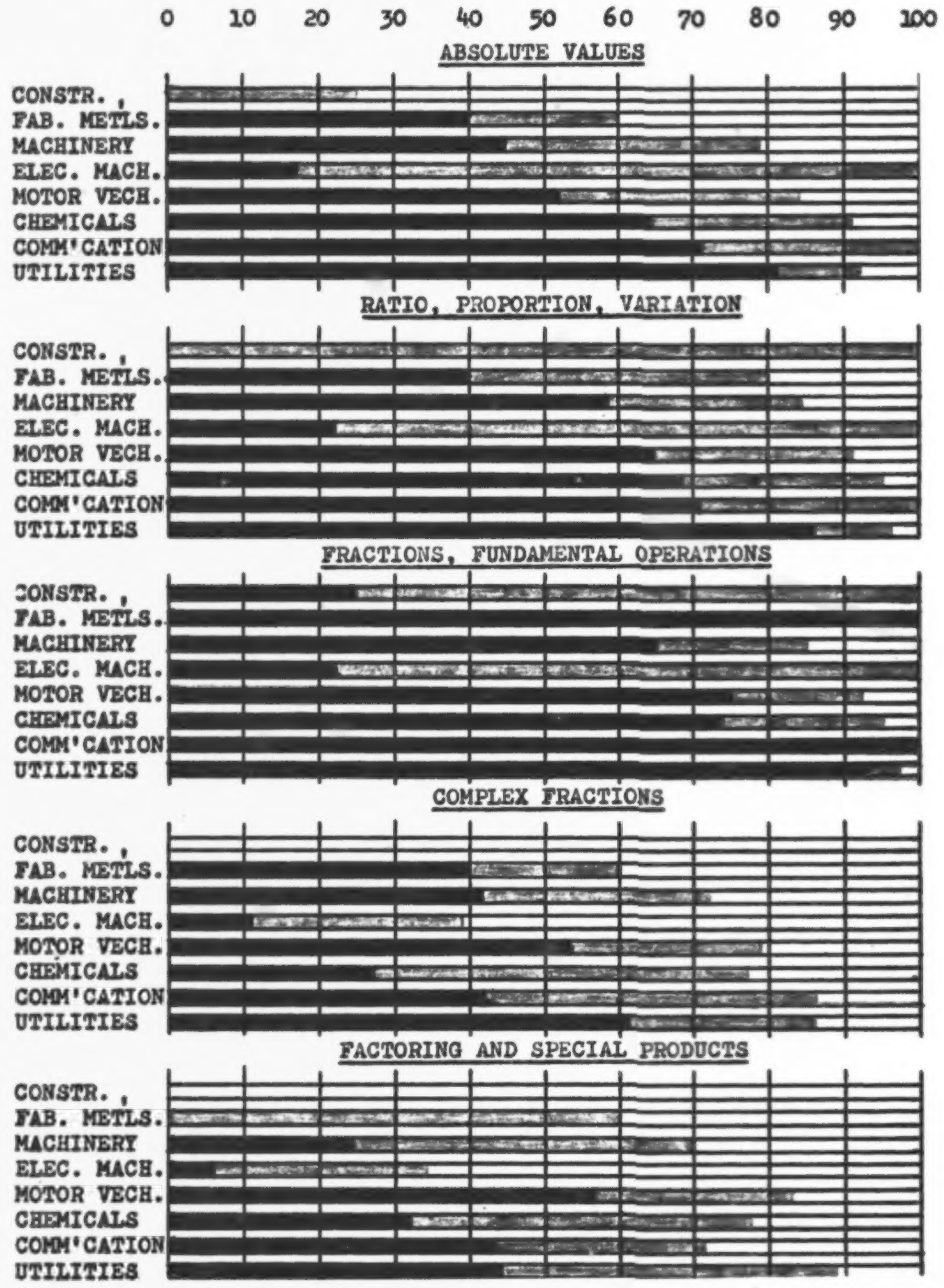

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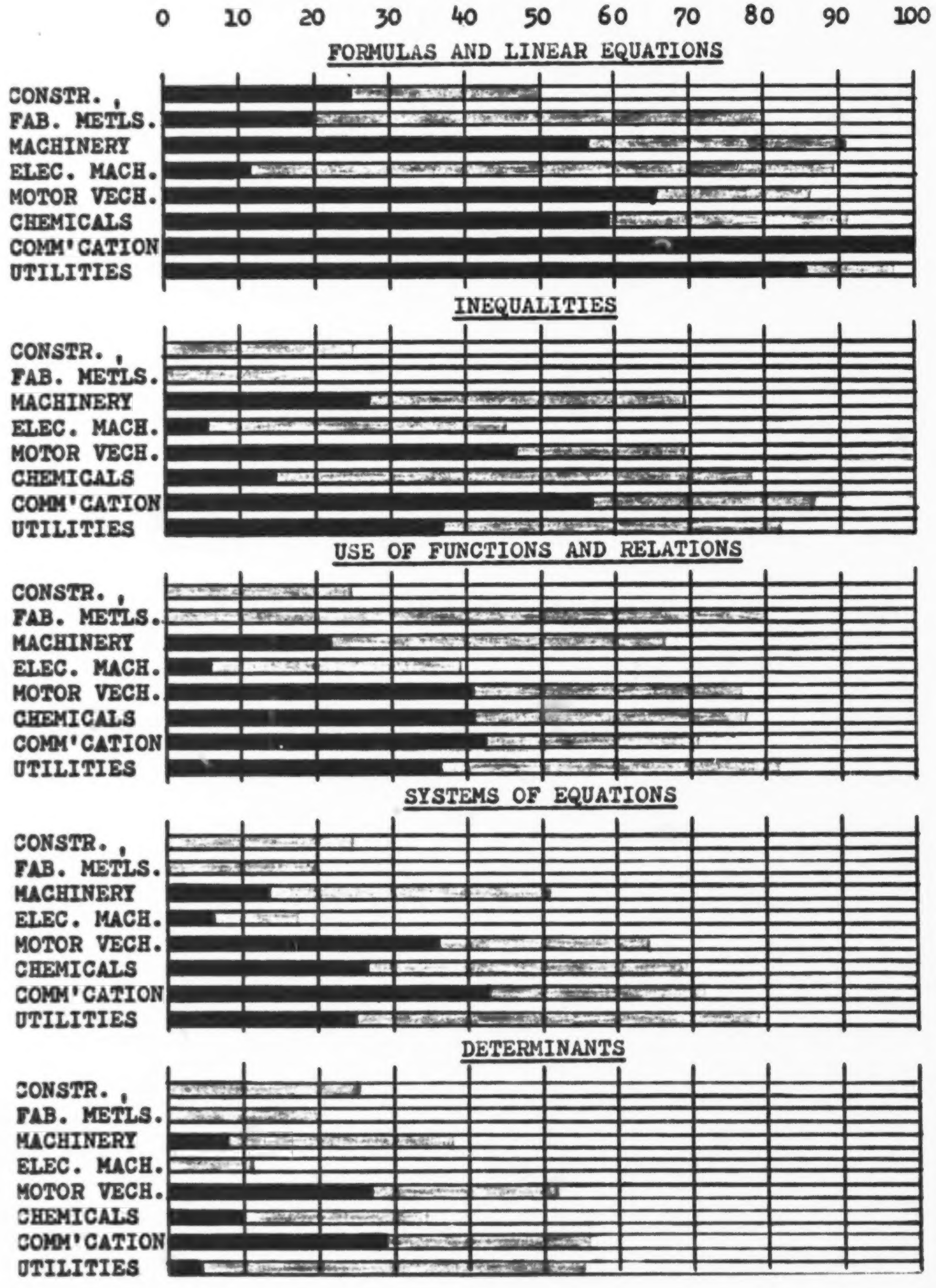

Fig. 5--Type of Industry continued

Fig. 5--Type of Industry continued

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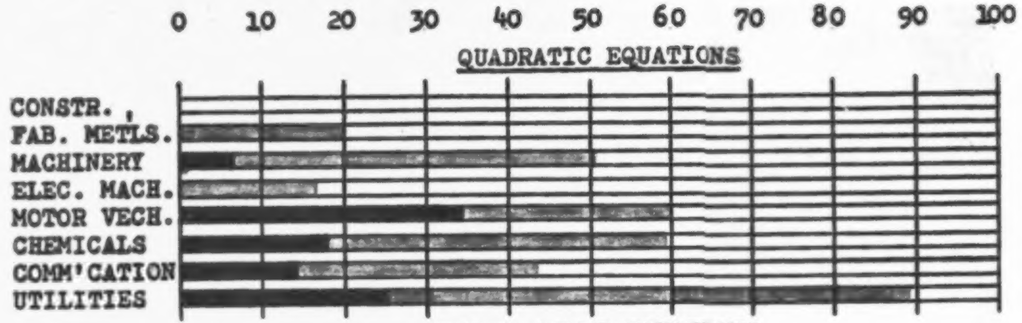
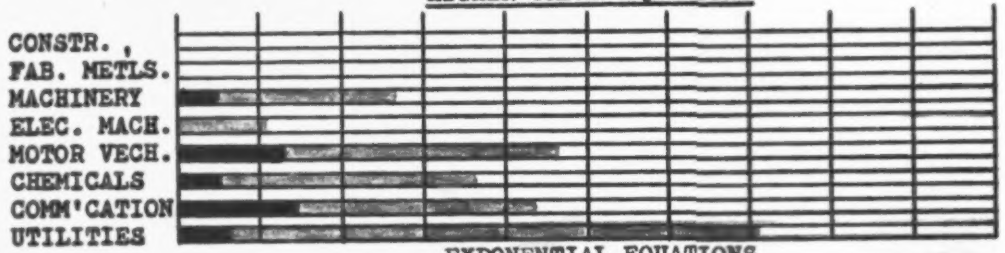
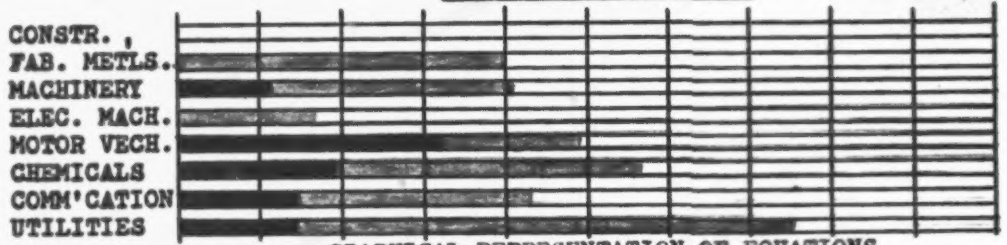


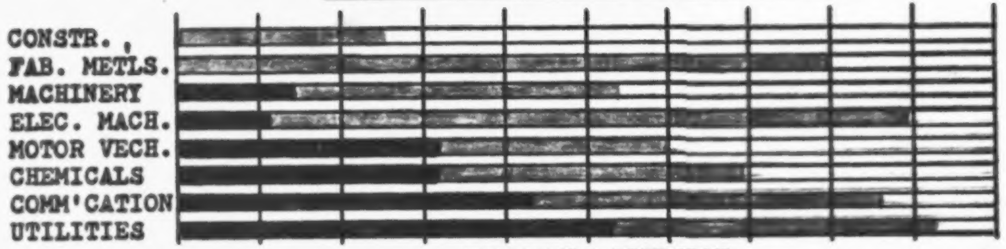
HIGHER ORDER EQUATIONS



EXPONENTIAL EQUATIONS



GRAPHICAL REPRESENTATION OF EQUATIONS



SYNTHETIC DIVISION

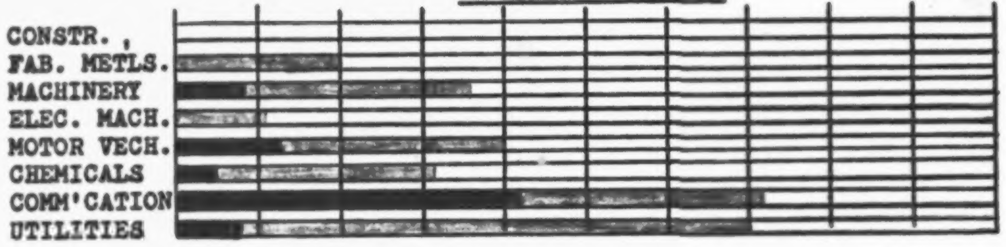
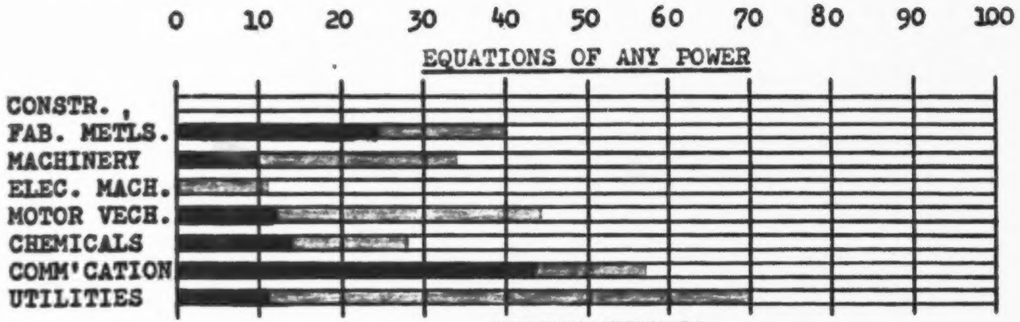
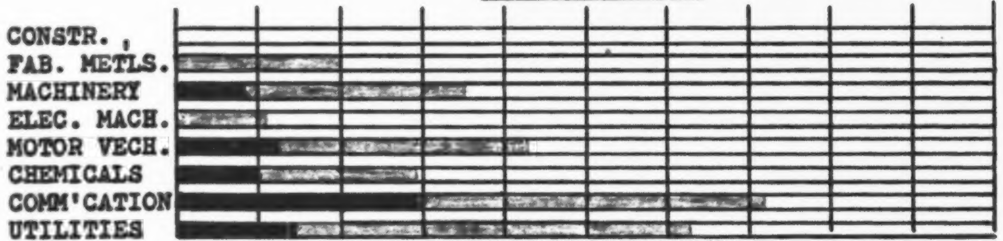


Fig. 5--Type of Industry continued

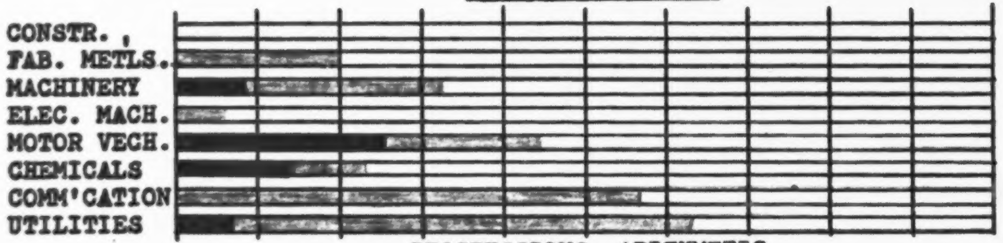
EQUATIONS OF ANY POWER



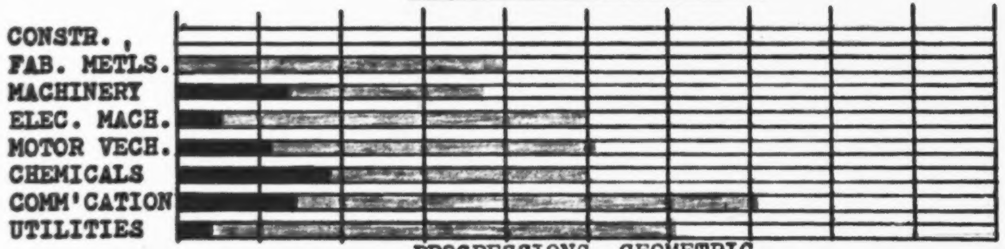
COMPLEX NUMBERS



BINOMINAL THEOREM



PROGRESSIONS, ARITHMETIC



PROGRESSIONS, GEOMETRIC

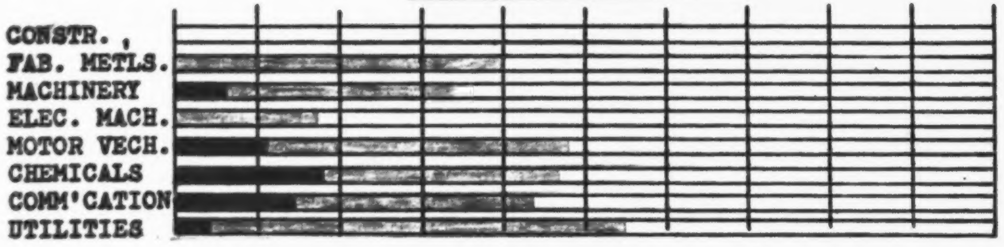


Fig. 5--Type of Industry *continued*

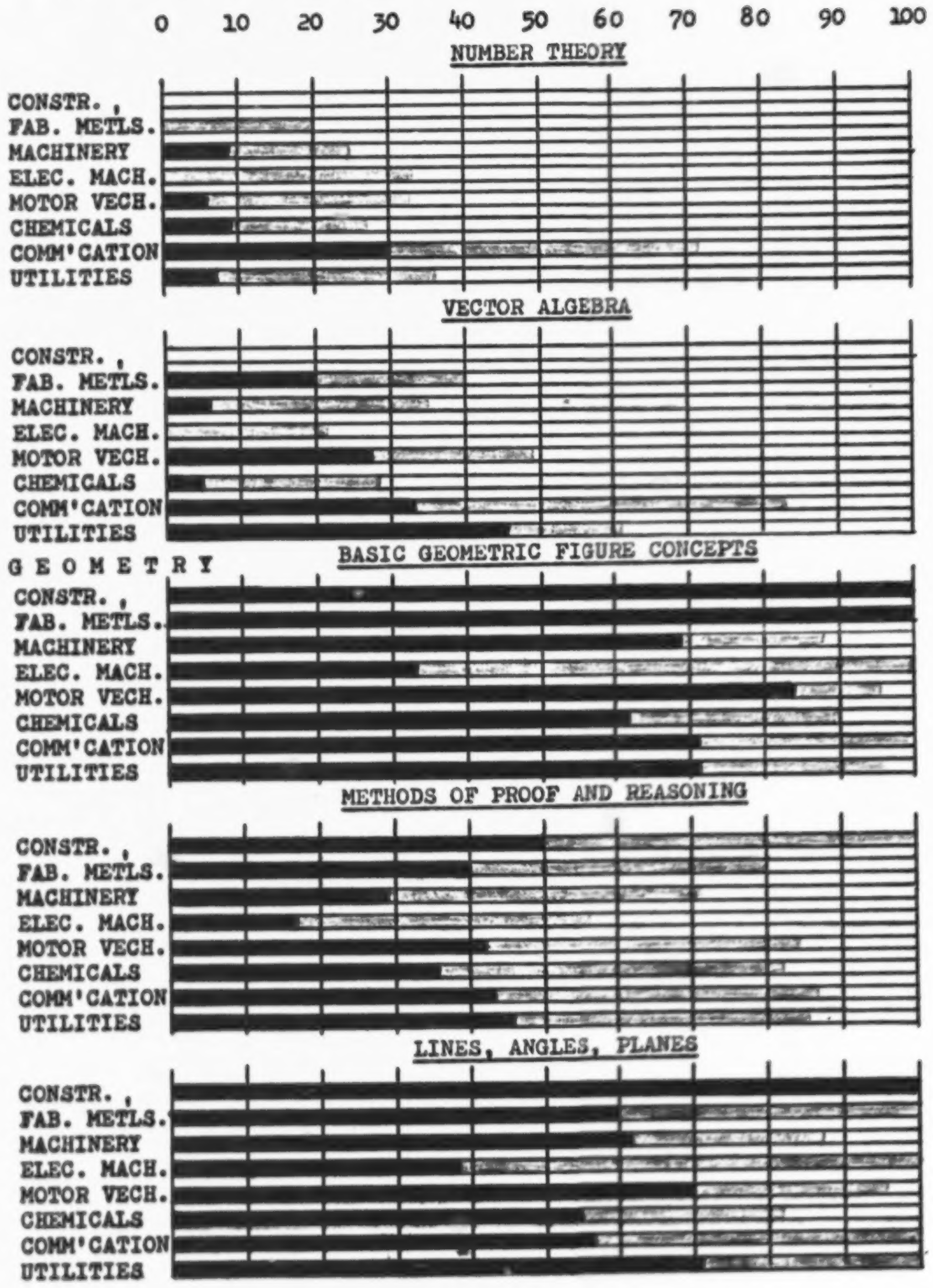


Fig. 5--Type of Industry *continued*

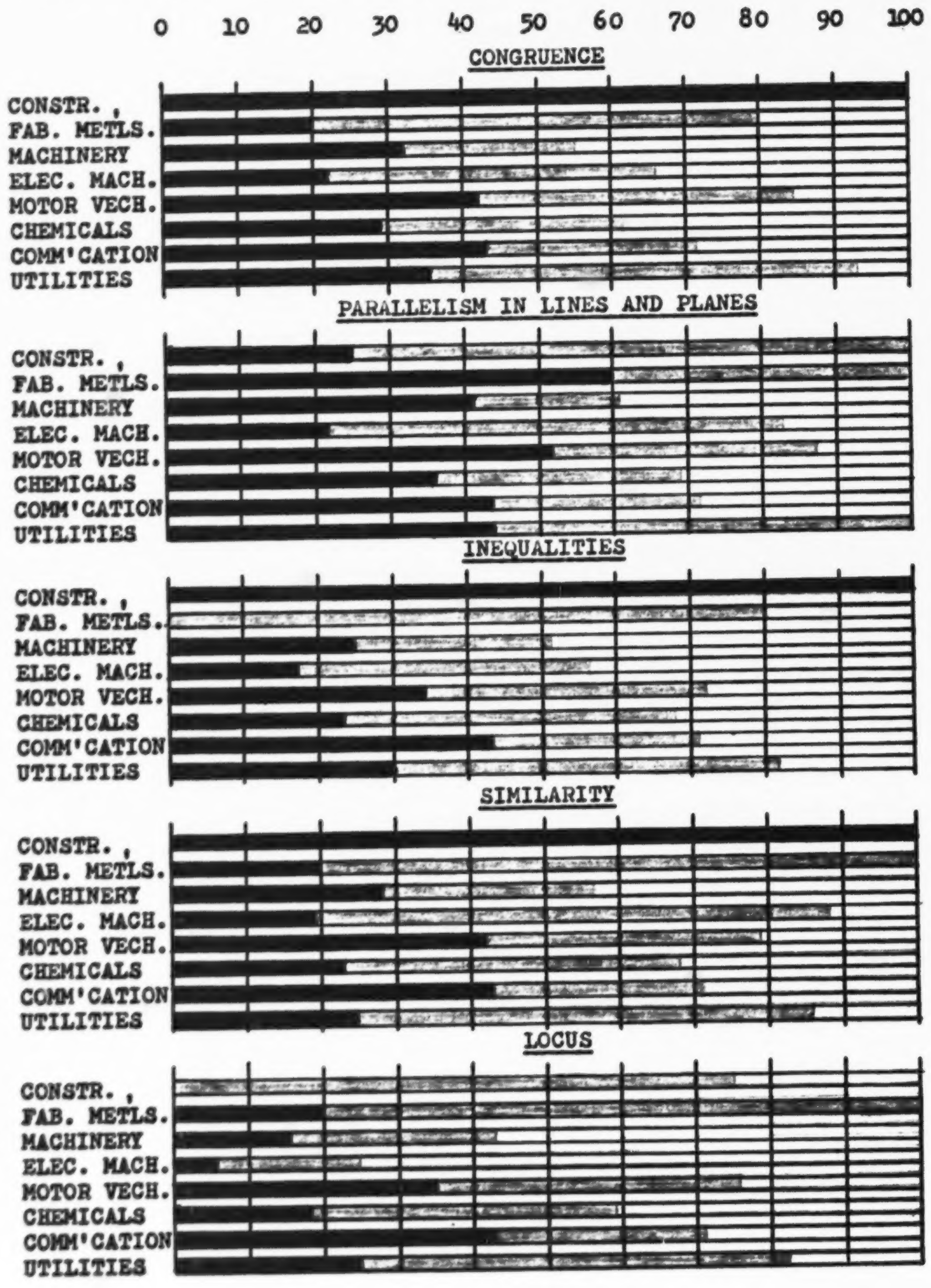
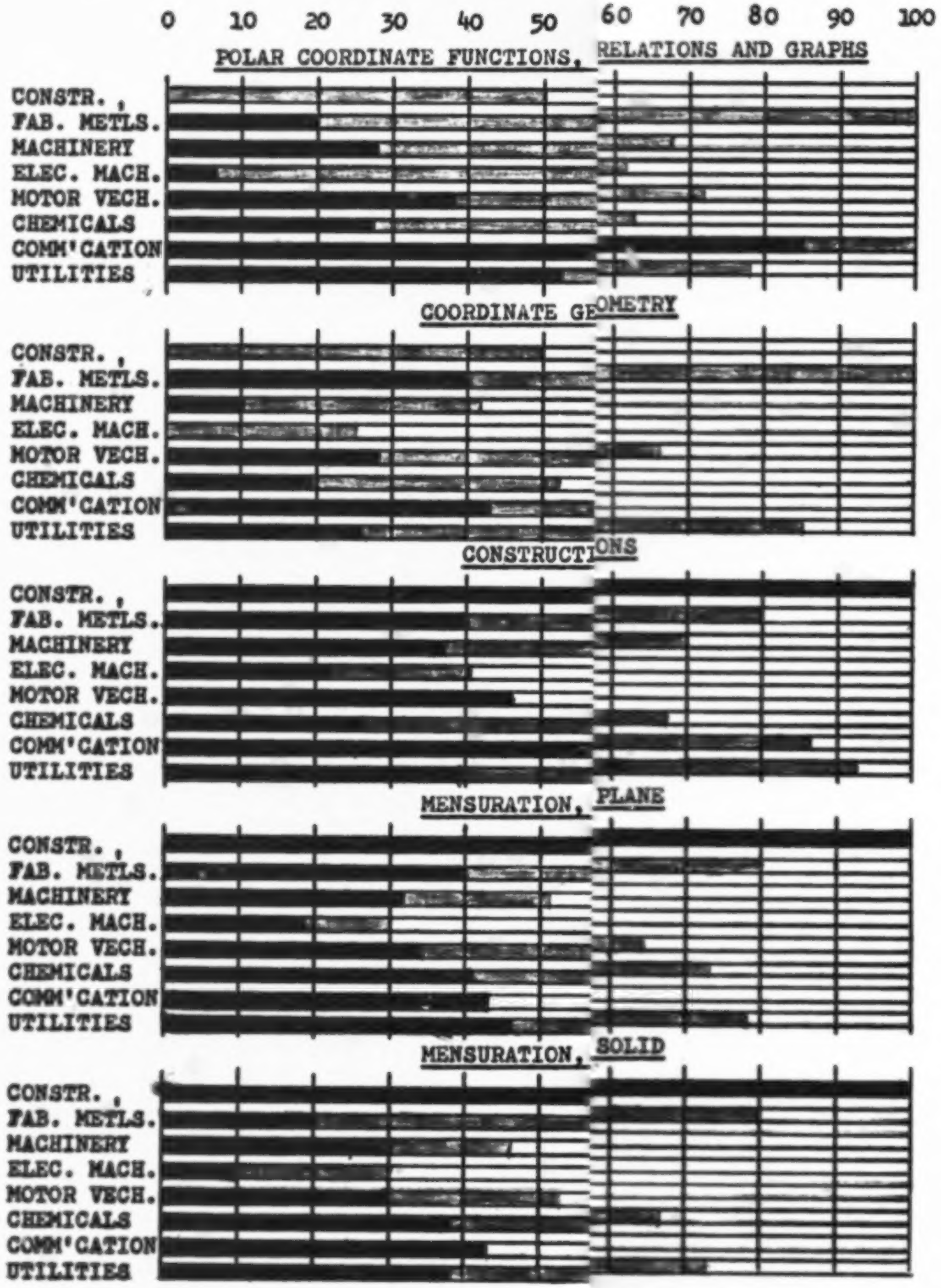


Fig. 5--Type of Industry continued


POLAR COORDINATE FUNCTIONS, RELATIONS AND GRAPHS

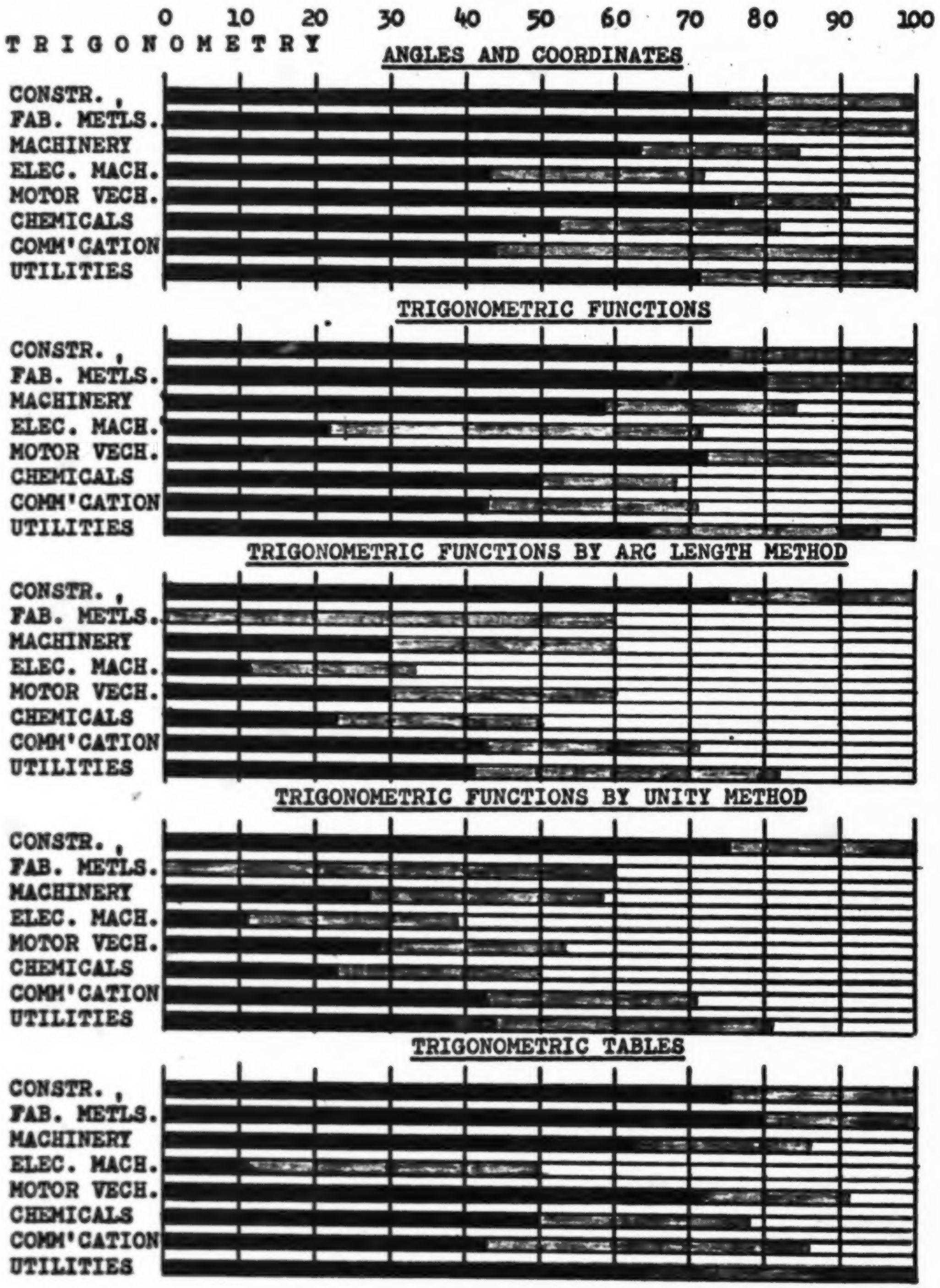
COORDINATE GEOMETRY

CONSTRUCTIONS

MENSURATION, PLANE

MENSURATION, SOLID

Fig. 5--Type of Industry continued


TRIGONOMETRY

ANGLES AND COORDINATES

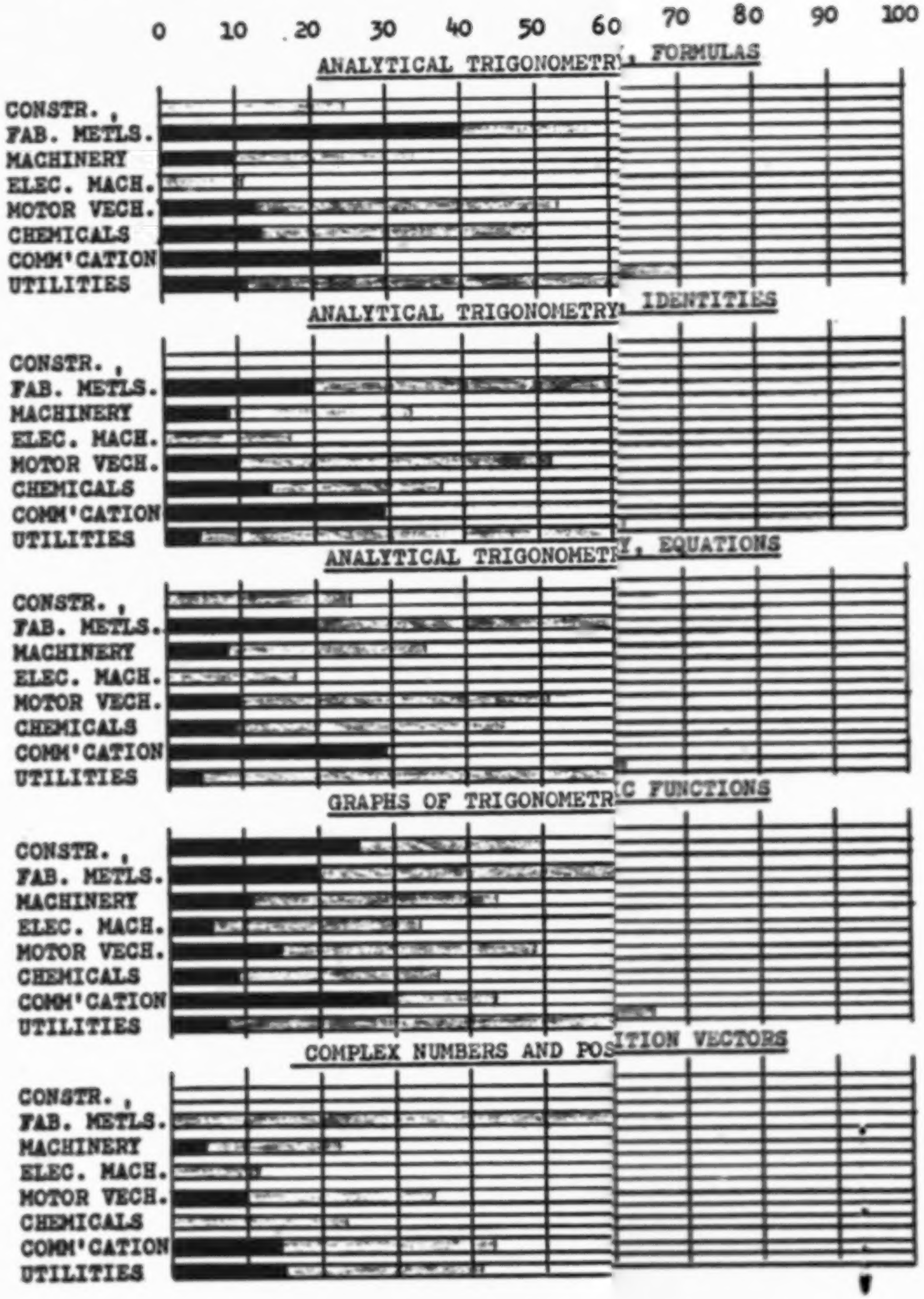
TRIGONOMETRIC FUNCTIONS

TRIGONOMETRIC FUNCTIONS BY ARC LENGTH METHOD

TRIGONOMETRIC FUNCTIONS BY UNITY METHOD

TRIGONOMETRIC TABLES

Fig. 5--Type of Industry continued


ANALYTICAL TRIGONOMETRY, FORMULAS

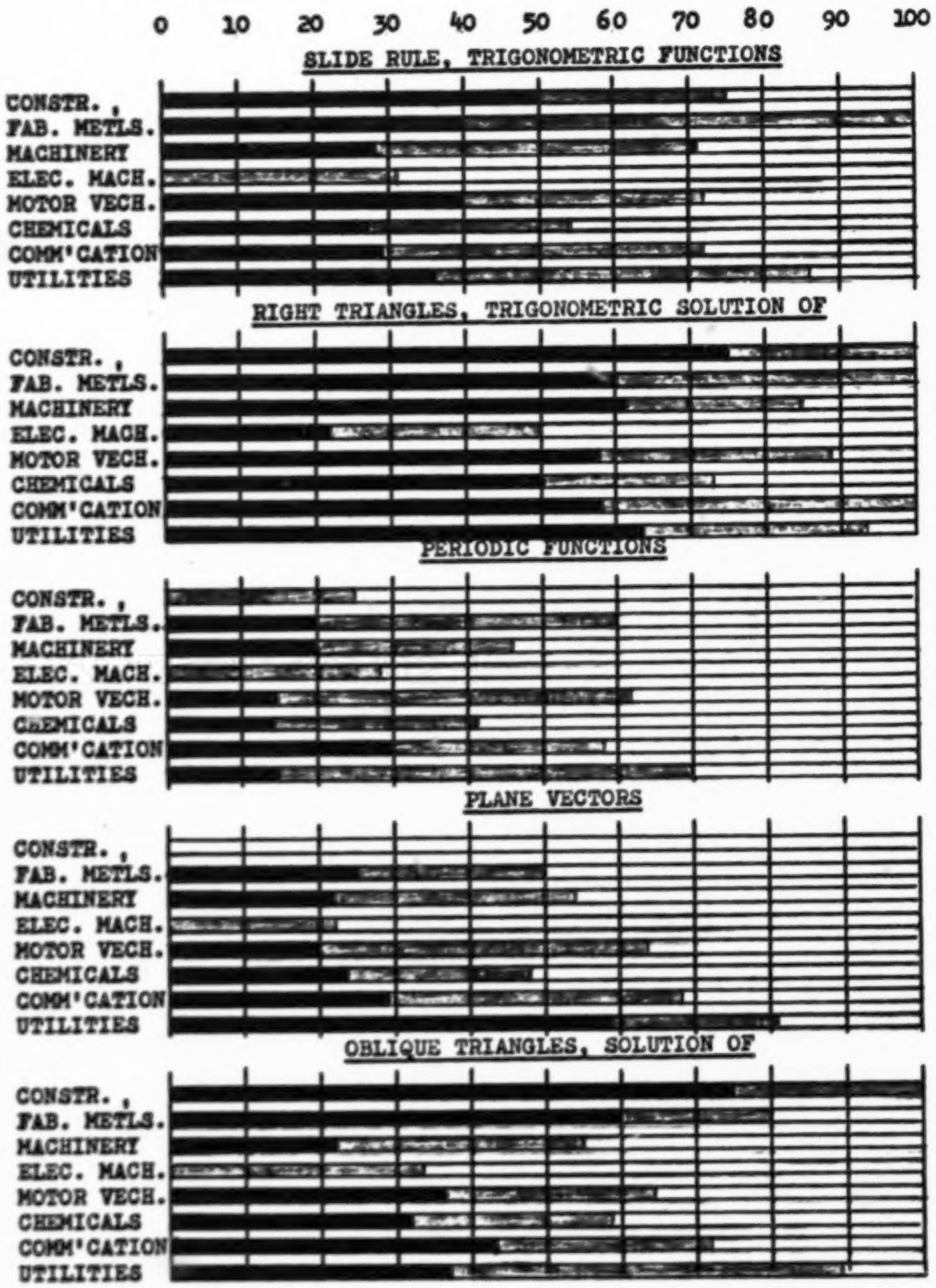
ANALYTICAL TRIGONOMETRY, IDENTITIES

ANALYTICAL TRIGONOMETRY, EQUATIONS

GRAPHS OF TRIGONOMETRIC FUNCTIONS

COMPLEX NUMBERS AND POSITION VECTORS

Fig. 5--Type of Industry continued


SLIDE RULE, TRIGONOMETRIC FUNCTIONS

RIGHT TRIANGLES, TRIGONOMETRIC SOLUTION OF

PERIODIC FUNCTIONS

PLANE VECTORS

OBLIQUE TRIANGLES, SOLUTION OF

Fig. 5--Type of Industry continued

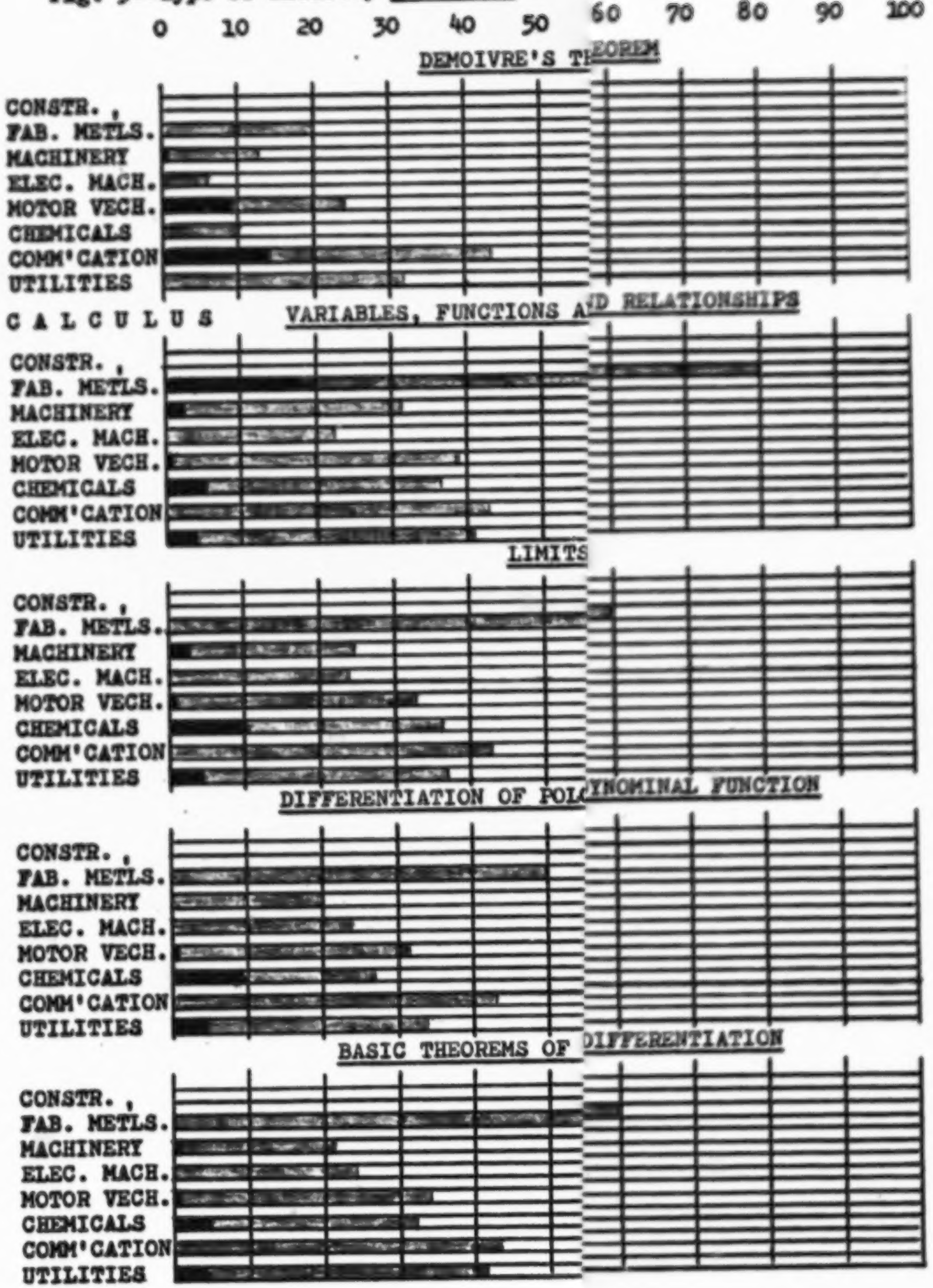


Fig. 5--Type of Industry continued

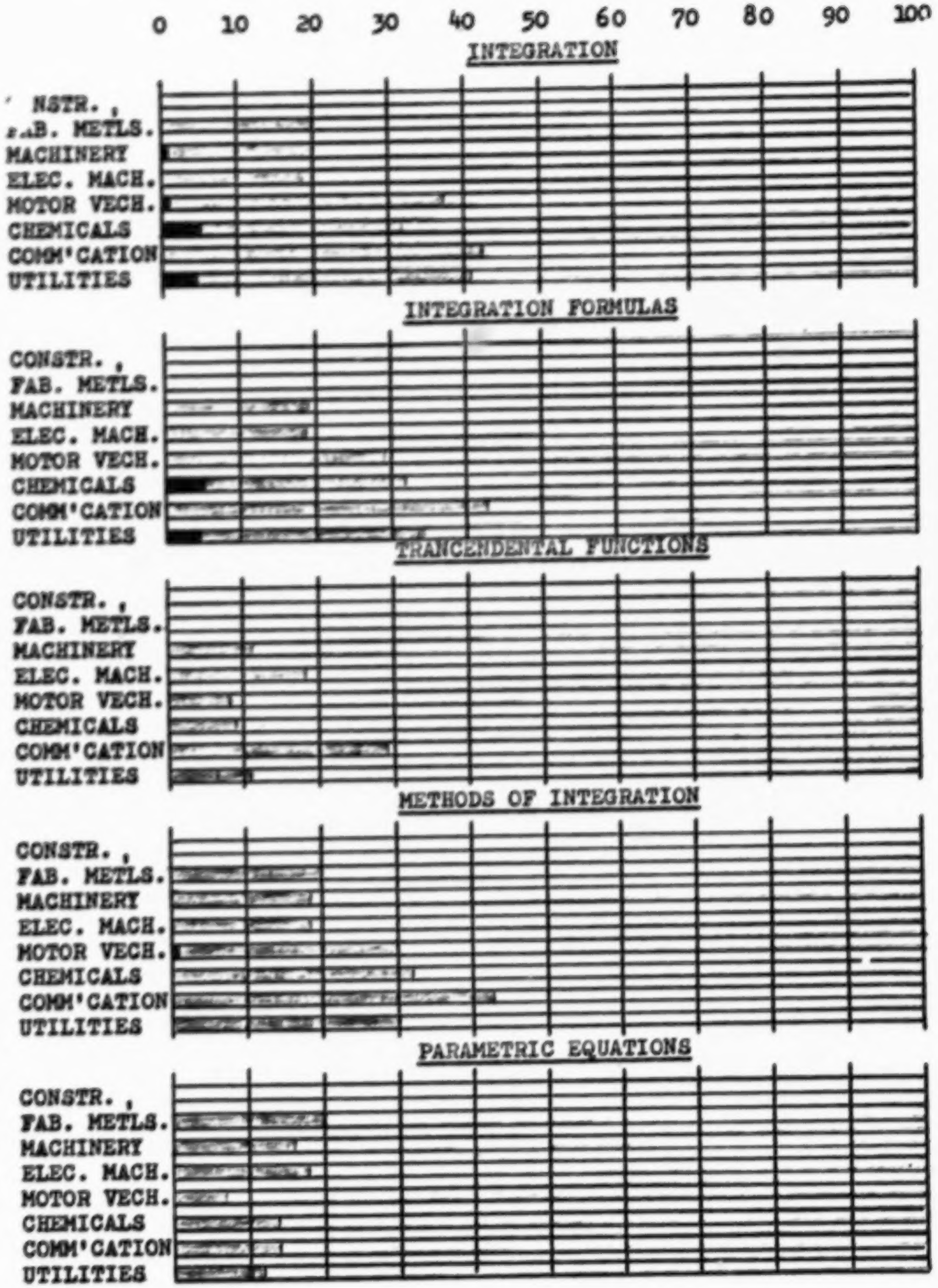
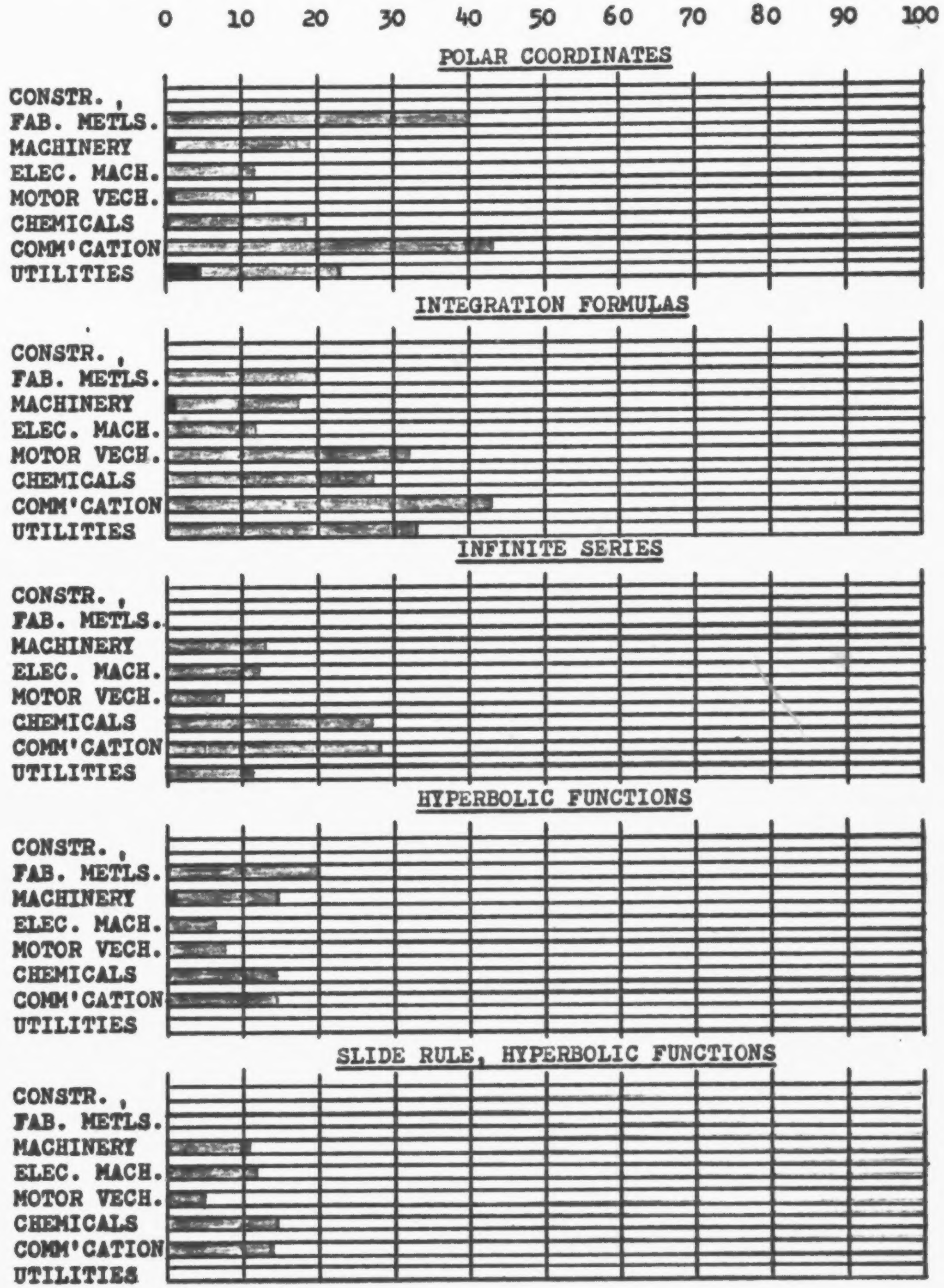


Fig. 5--Type of Industry continued



POLAR COORDINATES

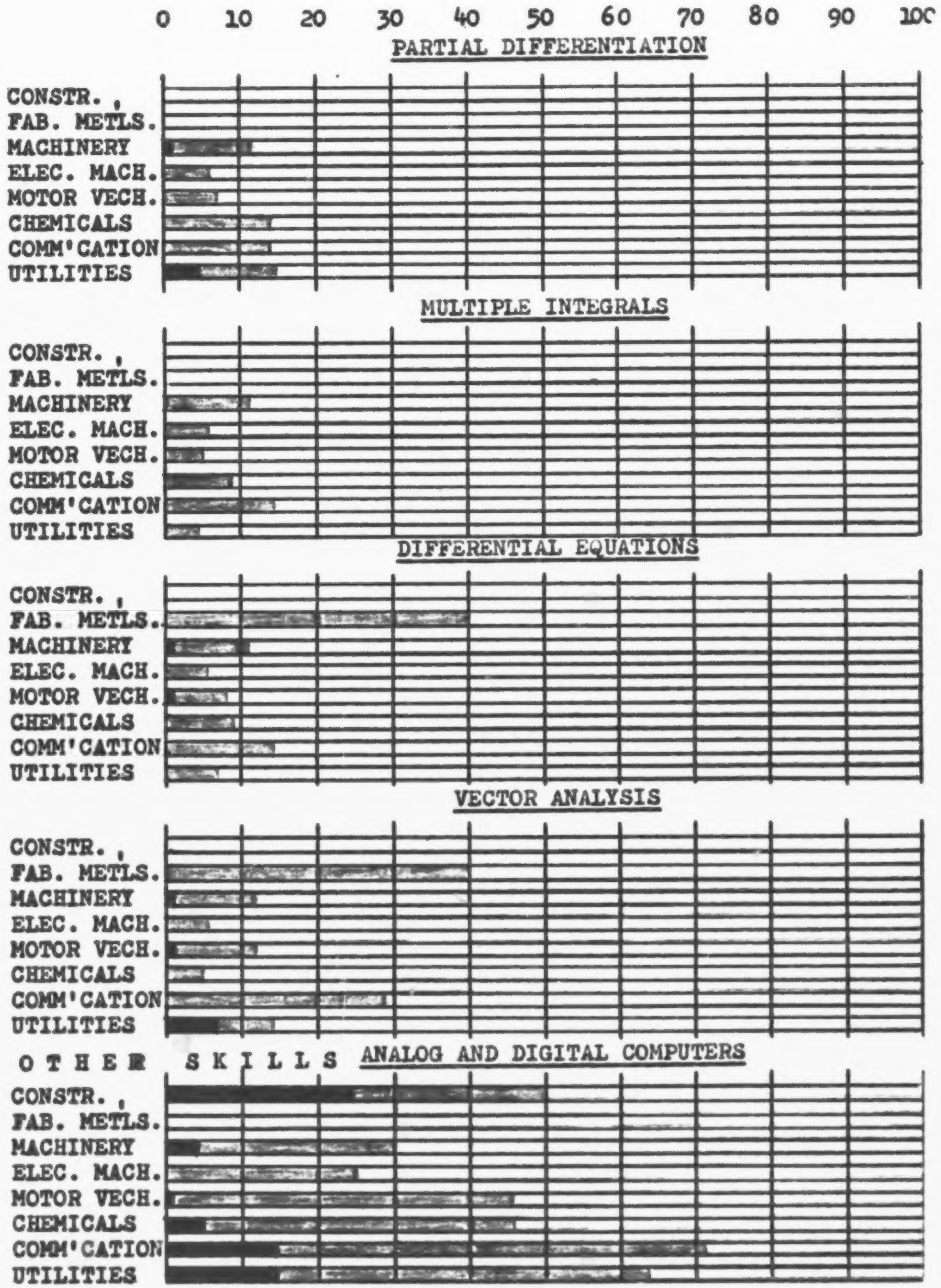
INTEGRATION FORMULAS

INFINITE SERIES

HYPERBOLIC FUNCTIONS

SLIDE RULE, HYPERBOLIC FUNCTIONS

Fig. 5--Type of Industry continued



PARTIAL DIFFERENTIATION

MULTIPLE INTEGRALS

DIFFERENTIAL EQUATIONS

VECTOR ANALYSIS

O T H E R S K I L L S ANALOG AND DIGITAL COMPUTERS

Fig. 5--Type of Industry continued

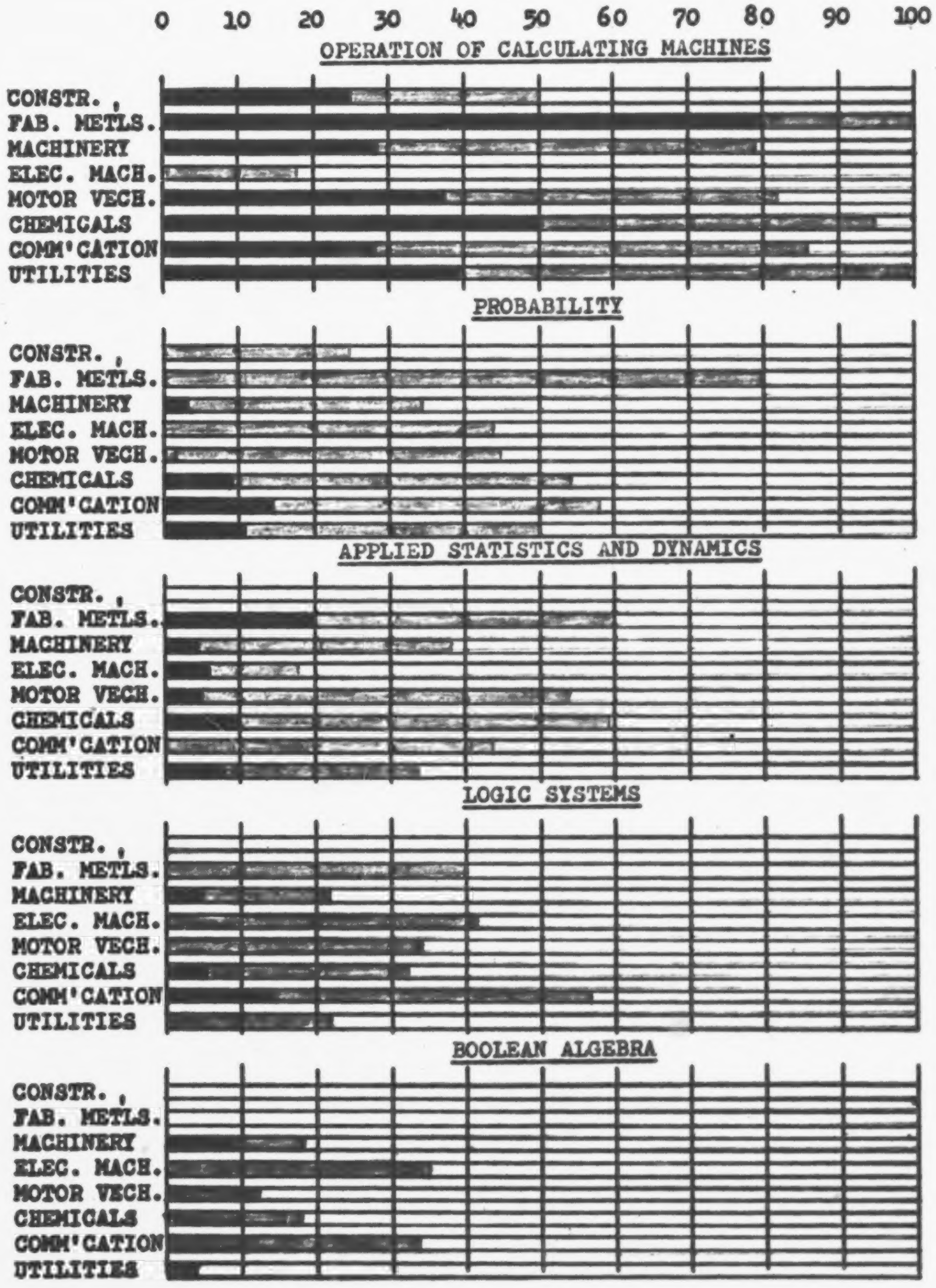
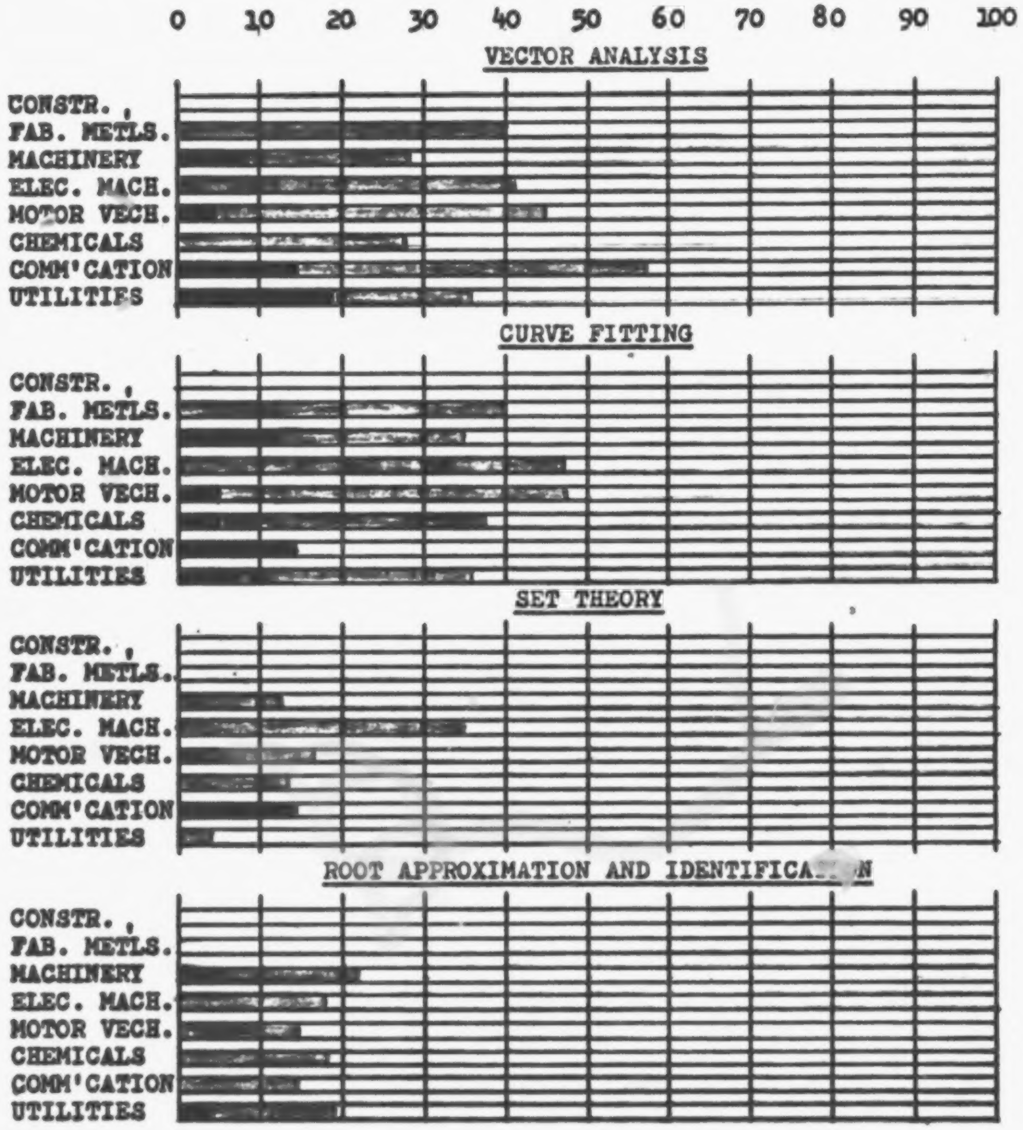


Fig. 5--Type of Industry continued



APPENDIX B

Research Instruments

The various instruments used in conducting the inquiry are contained in this Appendix. They are the working documents of the study and appear in this Appendix according to the following numbers:

1. The first letter was sent to the chief resident administrative officer of each company selected, as indicated in Appendix E. Usually this was the president or general manager, if the company was headquartered in Michigan. When a division of a larger company was contacted, the letter often went to a vice-president or a division manager.

2. The second letter went to the person recommended in the reply to the original request. Usually this was followed by a telephone call seeking an appointment, but sometimes the first reply actually established an interview date and made the second letter unnecessary.

3. The interview questions were enclosed with the letters and used in the actual interviews, (although not necessarily in the sequence printed).

4. The mathematical checkoff list, used to collect the data presented in Appendix A, appears in this Appendix. Technicians were requested to rate each mathematical skill as **Essential, Desirable,** or **Not Needed** in relation to their jobs.

5. A working definition was developed and supplied to all who were interviewed or contacted about the study. A description of its use is found on page 2.

6. The list of technologies — that was considered for classification purposes has been included in Appendix B. Those technologies that were actually identified by Michigan industries are marked.

WAYNE STATE UNIVERSITY
COLLEGE OF EDUCATION
DETROIT 2, MICHIGAN
DEPARTMENT OF INDUSTRIAL EDUCATION

APPENDIX B1

First Letter to Companies

Manpower needs for scientists and engineers are widely known and present shortages almost certainly will become greater. The need for technical personnel (definition on enclosure) is not so clearly understood and deserves greater attention. It has been estimated that by 1970 the highly skilled technical occupations will account for more than half of all job opportunities. Institutions providing technical instruction have the responsibility of determining the needs of technicians, if the estimated 100,000 technicians graduating each year by 1970 are to meet the requirements of industry. We know that mathematics and science are the foundation on which technical education programs are built. Thus, it seems essential to review present offerings and to give careful attention to the type and amount of mathematics needed by technicians.

Participating firms have been selected on the basis of location, size, function, and evidence of leadership in the use of technical personnel. A panel of consultants representing education, government, labor, and industry has chosen your organization to help in the determination of the mathematical fundamentals necessary for technicians to perform their daily tasks. The study is being conducted under the direction of Dr. G. Harold Silvius, Professor and Chairman, Department of Industrial Education, Wayne State University, in cooperation with the Henry Ford Community College and with the assistance of the Division of Vocational Education, Michigan Department of Public Instruction.

It is our hope that you will want to assist in this investigation by allowing us to interview key personnel in your organization. I would like to visit with a person(s) having a good understanding of current and anticipated technical personnel needs, and also a working knowledge of the fundamentals of mathematics required to perform the tasks to which technical personnel are assigned. I would like to record the interviews so that responses can be efficiently and accurately studied. Enclosed is a sample of the questions to be used in the interviews.

If you are willing to have your organization participate in this study, it would be greatly appreciated if you would send me the name and title of the person(s) with whom I should seek an appointment. We feel that your assistance is importand in helping to determine curriculum needs for training technicians for Michigan's industries. The significant findings of the study will be reported to you through a bulletin that will be published to report the findings.

Sincerely,

Norman G. Laws, Researcher
Henry Ford Community College

NGL:lb

Enclosures

DEARBORN PUBLIC SCHOOLS
HENRY FORD COMMUNITY COLLEGE
DEARBORN, MICHIGAN
271-2750

JAMES O. McCANN, DEAN

APPENDIX B2

Second Letter to Companies

Your president has suggested that I consult with you about the experiences your company is having with technicians (definition enclosed) especially their abilities in mathematics.

We are conducting a study to determine the mathematical needs of the 100,000 technical students now annually being prepared to meet the employment needs of industry. The study is being conducted under the direction of Dr. G. Harold Silvius, professor and chairman, department of industrial education, Wayne State University, in cooperation with the Henry Ford Community College and with the assistance of the division of vocational education, Michigan Department of Public Instruction.

I plan to be in your city during the week of and hope that it will be convenient for you to schedule an appointment with me. Enclosed you will find a copy of the questions that I would like to ask and a checkoff sheet for more specific responses relative to mathematical fundamentals. To assure accuracy in reporting and to expedite the interview, I would like to use a tape recorder. The responses, of course, will be considered confidential and the tape will be destroyed once the data has been converted to the statistical forms. Also, I am enclosing a personal data sheet that I hope we may include in the study. Please do not indicate your name or the name of your company on this form.

If the above arrangements are agreeable to you, I shall ask for an appointment, through your secretary. If you are unable to participate on this date, perhaps you can advise me of an alternate date or indicate another person in your organization for me to contact.

Sincerely,

Norman G. Laws
Researcher
Teacher, HFCC

NGL:lb
Enclosures

APPENDIX B3

Interview Questions

1. What types of technicians do you employ? Do you classify them by the type of job, by the amount of skill required, or by some other designation?
2. What is the source (training) of the personnel that you classify as technical? Are they usually upgraded non-technical employees, down-graded engineers, college students that are engineer dropouts, or the product of a technical institute, community college or other post high school institution?
3. Do you feel that men currently being hired as technicians who are products of post high school institutions are adequately prepared mathematically to perform their duties? In what, if any, mathematical functions do they seem to be deficient?
4. Do the jobs that technicians perform require a lesser amount of mathematical skill than is expected of engineers? If so, what fundamentals of mathematics are necessary for engineers but not considered essential for technicians?
5. Do you feel that the technicians you now have are prepared mathematically to meet the needs of their jobs for the next ten years? If not, how do you feel that they should obtain additional skill?
6. Do you feel that before a technician is hired, he should have all the mathematical skill that will be required of his job for at least the first ten years? If not, how should he achieve further training?
7. Do different types of technicians (as indicated in question 1) require a different amount of mathematical skill? Give some examples of differences in their mathematical requirements.
8. Please have filled out the attached mathematical checkoff list for each type of technician listed in questions 1 and 8. (If certain categories have identical requirements simply show more than one title at the top of the form. Otherwise, please use a separate form for each classification of technician.)
9. Please make any additional comments you would like to about the mathematical skills needed by technicians, about the type of mathematics that should be taught to these students, about the way technical mathematics should be taught, or anything else.

APPENDIX B4

MATHEMATICAL EXPECTATIONS OF TECHNICIANS IN MICHIGAN INDUSTRY

Mathematical Fundamentals Checkoff List

***INSTRUCTIONS:** Please check each item according to the degree of skill required by this type of technician.*

Name of Company ______________________ Type of Industry ______________________

____ Technician
(fill in)

Description of Duties ____

____

____

Arithmetic Skills	ESSENTIAL	DESIRABLE	NOT NEEDED
9 Fundamental Operations (addition, subtraction, multiplication, division)			
10 Fractions, Common and Decimal			
11 Standard Notation and Significant Figures			
12 Slide Rule, Multiplication and Division			
13 Slide Rule, Ratio and Proportion			
14 Slide Rule, Powers and Roots			
15 Slide Rule, Common Logarithms			
16 Slide Rule, Natural Logarithms			
17 Slide Rule, Percent and Interest			
18 Approximation and Estimation			
19 Conversions (weights and measure) (English and Metric)			
20 Measuring (rule, micrometer, vernier)			
21 Tables and Interpolation			
22 Percentage and Interest			
23 Ratio and Proportion			
24 Common Logarithms			
25 Natural Logarithms			
26 Plain and Differential Indexing			
27 Gears and Gear Ratio			
28 Screw Threads and Spirals			
29 Complex Gear Ratio and Lead Screws			

Mathematical Fundamentals ______________________________ **Technician**
(fill in)

CHECKOFF LIST, Page 2

ALGEBRAIC SKILLS	ESSENTIAL	DESIRABLE	NOT NEEDED
33 Explicit and Literal Numbers			
34 Symbolic Expressions			
35 Fundamental Operations with Literal Symbols (addition, subtraction, multiplication, division)			
36 Signs of Aggregation (parentheses etc.)			
37 Absolute Values			
38 Ratio, Proportion, Variation			
39 Fractions, Fundamental Operations			
40 Complex Fractions			
41 Factoring and Special Products			
42 Formulas and Linear Equations			
43 Inequalities			
44 Use of Functions and Relations			
45 Systems of Equations			
46 Determinants			
47 Quadratic Equations			
48 Higher Order Equations			
49 Exponential Equations			
50 Graphical Representation of Equations			
51 Synthetic Division			
52 Equations of Any Power			
53 Complex Numbers			
54 Binominal Theorem (expansion of binominals)			
55 Progressions, Arithmetic			
56 Progressions, Geometric			
57 Number Theory			
58 Vector Algebra			
59			
60			
61			

Mathematical Fundamentals ______________________________ **Technician**
(fill in)

CHECKOFF LIST, Page 3

GEOMETRIC SKILLS	**ESSENTIAL**	**DESIRABLE**	**NOT NEEDED**
62 Basic Geometric Figure Concepts			
63 Methods of Proof and Reasoning (including axioms, definitions, undefined terms, and assumptions of logic)			
64 Lines, Angles, Planes			
65 Congruence			
66 Parallelism in Lines and Planes			
67 Inequalities			
68 Similarity			
69 Locus			
70 Polar Coordinate Functions, Relations and Graphs			
71 Coordinate Geometry (analytic)			
72 Constructions			
73 Mensuration, Plane			
74 Mensuration, Solid			
75			
76			
77			
TRIGONOMETRIC SKILLS			
78 Angles and Coordinates			
79 Trigonometric Functions			
80 Trigonometric Functions by Arc Length Method			
81 Trigonometric Functions by Unity Method			
82 Trigonometric Tables			
83 Slide Rule, Trigonometric Functions			
84 Right Triangles, Trigonometric Solution of			
85 Periodic Functions			
86 Plane Vectors			
87 Oblique Triangles, Solution of			
88 Analytical Trigonometry, Formulas			
89 Analytical Trigonometry, Identities			
90 Analytical Trigonometry, Equations			
91 Graphs of Trigonometric Functions			
92 Complex Numbers and Position Vectors			
93 DeMoivre's Theorem			
94			
95			
96			

Mathematical Fundamentals ______________________________ **Technician**
(fill in)

CHECKOFF LIST, Page 4

CALCULUS SKILLS	ESSENTIAL	DESIRABLE	NOT NEEDED
97 Variables, Functions and Relationships			
98 Limits			
99 Differentiation of Poloynominal Function			
100 Basic Theorems of Differentiation			
101 Integration			
102 Integration Formulas			
103 Trancendental Functions			
104 Methods of Integration			
105 Parametric Equations			
106 Polar Coordinates			
107 Integration Formulas (basic)			
108 Infinite Series			
109 Hyperbolic Functions			
110 Slide Rule, Hyperbolic Functions			
111 Partial Differentiation			
112 Multiple Integrals			
113 Differential Equations			
114 Vector Analysis			
115			
116			
117			
Additional Mathematical Skills			
118 Analog and Digital Computers			
119 Operation of Calculating Machines			
120 Probability			
121 Applied Statistics and Dynamics			
122 Logic Systems			
123 Boolean Algebra			
124 Vector Analysis			
125 Curve Fitting			
126 Set Theory			
127 Root Approximation and Identification			

128 Additional Remarks: ______________________________

____

____

____

APPENDIX B5

Working Definition

What Is A Technician?

The technician is a special kind of person in industry. He holds a key spot between the engineer and the craftsman and has an understanding of theory as well as manipulative skills. Even within a single factory, different technicians may perform jobs ranging from simple testing projects to tasks requiring a high degree of creative and technical talent. The technician assists the engineer in planning and development work — as a draftsman, estimator, tester, or research technologist. He uses drawing instruments, gauges, applied science, mathematics, diagnosis and analysis, common sense, initiative and good judgement in turning the ideas and theories of the engineer into mass-produced items. He collects data, makes computations, performs laboratory tests and turns in reports. He builds, supervises, and controls the machines in plants and offices.[1]

The technician is a person whose chief interests and activities lie in the direction of testing, developing, applying and operating engineering and scientific equipment.[2] Under supervision he is capable of carrying out duties which may comprise: working on design and development; draftsmanship; inspecting and testing equipment; use of surveying instruments; maintaining machinery or engineering services and locating faults; or activities connected with research and development, sales and service, testing of components, advising consumers; and training.[3]

Sometimes technicians are classified according to their skills and knowledge as engineering or as industrial technicians. Often the classification is descriptive of the type of engineer that they assist. Some of the more popular types of technicians include: Electronics, Mechanical, Electrical, Civil and Construction, Electronic Data Processing and Computer Programming, Chemical and Metallurgical, Instrumentation, Aeronautical, Production, and Automotive.[4]

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[1] "Your Oppprtunities in Industry as a Technician" (New York National Association of Manufacturers, 1957), pp. 7-8.

[2] Prakken (Ed.), *Technician Education Yearbook* (Ann Arbor, Michigan: Prakken Publications, Inc., 1963), pp. 3-7.

[3] James L. McGraw (dir.) *Characteristics of Excellence in Engineering Technology Education* (Urbana, Illinois: American Society for Engineering Education, 1962), p. 12.

[4] Prakken, *Op. Cit.*, p. 74.

APPENDIX B6

The list indicates the categories of technicians used in the study.

What types of technical jobs do you have in your company for which a two-year post high school course would usually qualify a job applicant under each of the several categories?

Think in terms of the lowest level technical job of each category rather than positions that the employee might advance to after years of experience on the job.

Some Types of Technicians

*1. Aeronautical
2. Automotive
*3. Chemical
*4. Civil and Construction
*5. Data Processing
6. Diesel
*7. Drafting
*8. Electronics
9. Foundry
*10. Industrial
*11. Instrumentation
12. Job Methods
*13. Laboratory
14. Maintenance
15. Metal Products
*16. Mechanical
*17. Metallurgical
*18. Packaging
19. Tool Design
*20. Writer
*21. Fluid Power
22. Others

*identified in the study

APPENDIX C

Persons Invited to Serve on Task Force One

Mr. Louis Bettega, Manager of Technical Recruiting, Engineering Office, Chrysler Corporation, P.O. Box 118, Detroit, Michigan 48231

Mr. Elliott A. Browar, Assistant Regional Director, Bureau of Labor and Statistics, 1316 Ontario Street, Cleveland, Ohio 44114

Mr. William Forsythe, Community Relations Manager, International Business Machines Company, 7700 Second Blvd., Detroit, Michigan 48202

Mr. Raymond Gartha, Program Supervisor, Education Corporate Industrial Relations, Burroughs Corp., 707 W. Milwaukee Street, Detroit, Michigan 48232

Mr. Robert Holbeisen, Supervisor O.A.S.C., Michigan Employment Security Commission, 7310 Woodward Avenue, Detroit, Michigan 48202

Mr. Edward J. Huttenga, Director of Vocational Education, Muskegon Public Schools and Muskegon Community College, 8 D Larch Court Apts., Muskegon, Michigan.

Mr. Charles Langdon, Coordinator of Research, Division of Vocational Education, Department of Public Instruction, P.O. Box 928, Lansing, Michigan 48904

Mr. Thomas McKinnon, Manager of Salary Personnel & Training, Ford Motor Company, The American Road, Dearborn, Michigan 48128

Mr. Russell Maples, Director of Vocational Education, Lansing Public Schools, 437 Iris Street, Lansing, Michigan

Mr. Francis Mitchell, Consultant, Trade and Industrial Education, Department of Public Instruction, P.O. Box 928, Lansing, Michigan 48904

Mr. Fred Mitchell, Chief, Michigan Employment Security Commission, 7310 Woodward Avenue, Detroit, Michigan 48202

Mr. Stanley W. Puddiford, Community Relations Manager, Michigan Bell Telephone Company, Room 1313, 1365 Cass Avenue, Detroit, Michigan 48226

Mr. Rudy A. Silverstone, Director of Vocational Education, Ann Arbor Public Schools, 1810 Anderson Street, Ann Arbor, Michigan

Mr. Joseph V. Tuma, Director of Manpower Training, U.A.W., International Union, Solidarity House, 8000 E. Jefferson Avenue, Detroit, Michigan 48214

Mr. Carl H. Turnquist, Division Director of Vocational Education, Detroit Public Schools, 5057 Woodward Avenue, Detroit, Michigan 48202.

Mr. Peter Wallus, Coordinator of Secondary Education, Kalamazoo Public Schools, Kalamazoo, Michigan

APPENDIX D

Standard Metropolitan Statistical Areas[1]

- Ann Arbor (172,440)
  - Washtenaw County
- Bay City (107,042)
  - Bay City County
- Detroit* (3,762,360)
  - Macomb County
  - Oakland County
  - Wayne County
- Flint (416,239)
  - Genesee County
  - Lapeer County
- Grand Rapids (461,906)
  - Kent County
  - Ottawa County
- Jackson (131,994)
  - Jackson County
- Kalamazoo (169,712)
  - Kalamazoo County
- Lansing (298,949)
  - Clinton County
  - Eaton County
  - Ingham County
- Muskegon - Muskegon Heights (149,943)
  - Muskegon County
- Saginaw (190,752)
  - Saginaw County

*Includes: East Detroit, Roseville, St. Clair Shores, Warren, Birmingham, Ferndale, Hazel Park, Madison Heights, Oak Park, Pontiac, Royal Oak, Southfield, Allen Park, Dearborn, Garden City, Hamtramck, Highland Park, Inkster, Lincoln Park, Livonia, Southgate, Wyandotte.

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[1] See page 3 for complete description of Standard Metropolitan Statistical Areas.

APPENDIX E

Manufacturing Firms Considered for the Study

This is a list of the Manufacturing Firms considered and selected for the study, by city. The firms nominated by Task Force One are indicated by an asterisk.

Ann Arbor

*Bendix Systems Division
3300 Plymouth Road
327 S. 4th Avenue

*Hoover Ball & Bearing Company
Bearing Division
5400 S. State Road

*King Seeley Thermos Company
King Seeley Division

Bay City

Defoe Shipbuilding Company
*Prestolite Div. of Eltra Corp.

Detroit

*Acme Quality Paints, Inc.
8250 St. Aubin Avenue 48211

*Allen Industries, Inc.
Leland & G.T.R.R. 48207

*American Metal Products Company
5959 Linsdale Avenue 48204

*American Motors Corporation
14250 Plymouth Road 48232

American Standard Controls Div.
5900 Trumbull Avenue 48208

American-Standard Industrial Div.
American Radiator & Standard
Sanitary Corporation
8111 Tireman Ave., P.O. Box 58

Barnes-Gibson, Raymond Div.
40300 Plymouth Road, P.O. Box 555
Plymouth 48170

*Bendix Corporation, The
1104 Fisher Building 48202

*Brennan Company
4649 Humboldt 48208

Budd Company, The,
Automotive Div.
12141 Charlevoix 48215

*BullDog Electric Products Division
I-T-E Circuit Breaker Co.
7610 Joseph Campau 48211

Bundy Tubing Company
8109 E. Jefferson 48214

*Burroughs Corporation
6071 Second Avenue 48232

Cadillac Gage Company
25760 Groesbeck Hwy., Warren

*Cadillac Motor Car Division
2860 Clark Avenue 48232

*Chrysler Corporation (Gen. Office)
341 Massachusetts Avenue
P.O. Box 1919 48231

*Congress Tool & Die Company
3300 Denton, Detroit 48211

*Couse Company, Walter L.
12740 Lyndon 48227

*Detrex Chemical Industries, Inc.
14331 Woodrow Wilson
P.O. Box 501 48232

Detroit Aluminum & Brass Co.
3975 Christopher Ave. 48214

*Detroit Edison Company, The
2000 Second Avenue 48226

Detroit Gasket & Mfg. Company
12640 Burt Road 48223

Detroit Steel Corporation
1025 South Oakwood, P.O. Box 4308

*DeVlieg Machine Company
2800 West 14 Mile Road
Royal Oak 48073

Ditzler Color Division
Pittsburgh Plate Glass Co.
8000 West Chicago 48204

Divco Division
Divco-Wayne Corporation
22000 Hoover Road

*Douglas & Lomason Company
5836 Lincoln 48208

Dura Corporation
21800 Greenfield, Oak Park 48237

*Eaton Manufacturing Company
9771 French Road 48213

Essex Wire Corporation
6233 Concord 48211

Evans Products Company
13101 Eckles Road, Plymouth

*Ex-Cell-O Corporation
1200 Oakman Blvd., P.O. Box 386

Federal-Mogul-Bower Bearings, Inc.
11031 Shoemaker 48213

*Ford Motor Company
The American Road, Dearborn

Fruehauf Corporation
10940 Harper Avenue 48232

*General Motors Corporation
General Motors Building 48202

*Great Lakes Steel Corporation
Tecumseh Road, Ecorse 48229

C. M. Hall Lamp Co.
1035 E. Hancock 48207

Higbie Manufacturing Company
4th and Water Streets
Rochester 48063

Holley Carburetor Company
11955 E. Nine Mile Road
P.O. Box A, Warren 48090

Huck Manufacturing Company
2480 Bellevue 48207

*International Business Machine Co.
7700 Second Avenue

*LaSalle Tool Company
21535 Hoover Road, Warren

Long Manufacturing Division
Borg-Warner Corporation
12501 Dequindre 48212

McCord Corporation
Riopelle at E. Grand Blvd.

*McLouth Steel Corporation
300 South Livernois 48217

*R. C. Mahon Company, The
6565 E. Eight Mile Road
P.O. Box 4666 48234

Massey-Ferguson, Inc.
12601 Southfield Road 48223

Mechanical Handling Systems, Inc.
12775 E. Nine Mile Road, Warren

*Metallurgical Products Dept.,
General Electric Company
11177 E. Eight Mile Road
P.O. Box 237 48232

*Michigan Bell Telephone Company
1365 Cass Avenue 48226

*Michigan Consolidated Gas Co.
One Woodward Avenue 48226

Michigan Seamless Tube Company
400 W. Avenue, South Lyon 48178

Michigan Tool Company
7171 E. McNichols Rd. 48212

Micromatic Hone Division
Ex-Cell-O Corporation
8100 Schoolcraft 48238

*Monsanto, Inorganic Chemical Div.
110 W. Jefferson, Trenton 48183

National Broach & Machine Co.
5600 St. Jean 48213

National Machine Products Co.
44225 Utica Road, Utica 48087

National Twist Drill & Tool Co.
6841 Rochester Rd., Rochester

*Parke, Davis and Company
Joseph Campau at River
P.O. Box 118 48232

*Pennsalt Chemicals Corporation
4655 Biddle, Wyandotte 48193

Purolator Products, Inc.
3927 Fourth Avenue, Wayne 48184

*Reichhold Chemicals, Inc.
601 Woodward Heights Blvd.
Ferndale 48220

Detroit — Continued

Revere Copper & Brass, Inc.
5851 West Jefferson Ave. 48209

*Rinshed-Mason Company
5935 Milford 48210

*Rockwell Standard Corporation
100-400 Clark Avenue 48232

*Royal Oak Tool & Machine Co.
30250 Stevenson Hwy., Royal Oak

*Solvay Process Division
Allied Chemical Corporation
7501 West Jefferson 48217

Stainless Steel Division
Jones & Laughlin Steel Corp.
21400 Mound Road, Warren
P.O. Box 4606 48234

Swedish Crucible Steel Company
8801 Conant Ave., Hamtramck 48211

*Thompson Ramo Wooldridge Inc.
Michigan Division
34201 Van Dyke Avenue
Warren 48090

*Udylite Corporation, The
1651 E. Grand Blvd. 48211

*U.S. Rubber Company
6600 E. Jefferson Avenue
P.O. Box 298 48232

*Vickers, Inc., Div. Sperry Corp.
Maple & Crooks Road
P.O. Box 506, Troy 48232

Jervis B. Webb Company
9000 Alpine 48204

Whitehead & Kales Company
58 Haltiner, River Rouge 48218

Whitman & Barnes Div.,
United Greenfield Corp.
40600 Plymouth Road, Plymouth

Wolverine Tube Division of
Calumet & Hecla Inc.
17200 Southfield
Allen Park 48101

Gar Wood Industries, Inc.
36253 Michigan Ave., Wayne 48184

Woodall Industries, Inc.
7565 E. McNichols Rd. 48234

N. A. Woodworth Company
1300 E. Nine Mile Road, Ferndale

*Wyandotte Chemicals Corporation
1609 Biddle Ave., Wyandotte

Zenith Carburetor
Division of Bendix Corporation
696 Hart Avenue 48214

Grand Rapids

*American Seating Company
901 Broadway Avenue NW

Doehler-Jarvis Division
National Lead Company
525 Cottage Grove SE

*Keeler Brass Company
955 Godfrey SW

*Lear Siegler, Inc.
4141 Eastern, SE

McInerney Spring & Wire Co.
655-725 Godfrey Ave. SW

*Packaging Corp. of America
415 Fulton Street E

*Steelcase Incorporated
1120 36th Street SE

Jackson

*Aeroquip Corporation
300 South East Avenue

*Clark Equipment Company
Transmission Division
1300 Falahee Road

*Consumers Power Company
212 W. Michigan

*Sparton Corp. Electronics Div.
2400 East Ganson Street

*Walker Manufacturing Company
Walker-Michigan Division
633 Hupp Avenue

Kalamazoo

*Checker Motors Corporation
2016 North Pitcher

Fuller Transmissions Division
222 Mosel Avenue

*KVP-Sutherland Paper Company
Island Ave. Parchment

*New York Air Brake Company
9000 East Michigan

*Pneumo Dynamics Corporation
2220 Palmer

*Shakespeare Company
241 East Kalamazoo

*Upjohn Company
7000 Portage Road

*Simpson Lee Paper Company
Vicksburg

Lansing

*Atlas Drop Forge
Division of Dana Corporation
209 W. Mt. Hope Avenue
P.O. Box 1050

*John Bean Division
FMC Corporation
1305 South Cedar Street

*Motor Wheel Corporation
1600 N. Larch Street

*White Motor Company Lansing Div.
1331 S. Washington Avenue

Muskegon

*Brunswick Corporation
525 W. Laketon

Campbell, Wyant & Cannon Foundry
Division of Textron Inc.
Henry Street

*General Telephone Co. of Michigan
860 Terrace Street

*Gerber Products Company
Fremont

Lakey Foundry Corporation
First and Water Streets

*Manning, Maxwell & Moore, Inc.
Crane & Hoist Division
414 W. Broadway

*Muskegon Piston Ring Company
1839 Sixth Street

*Sealed Power Corporation
2001 Sanford Street

*Westran Corporation
1148 W. Western Avenue

Saginaw

*Baker Perkins, Inc.
1000 Hess Street

*Dow Chemical Company
Midland

*Eaton Manufacturing Company
1000 Rust Street

*Lufkin Rule Company
1730 Hess Street

*The U.S. Graphite Company
Division, Wickes Corporation
1621 Holland Avenue

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